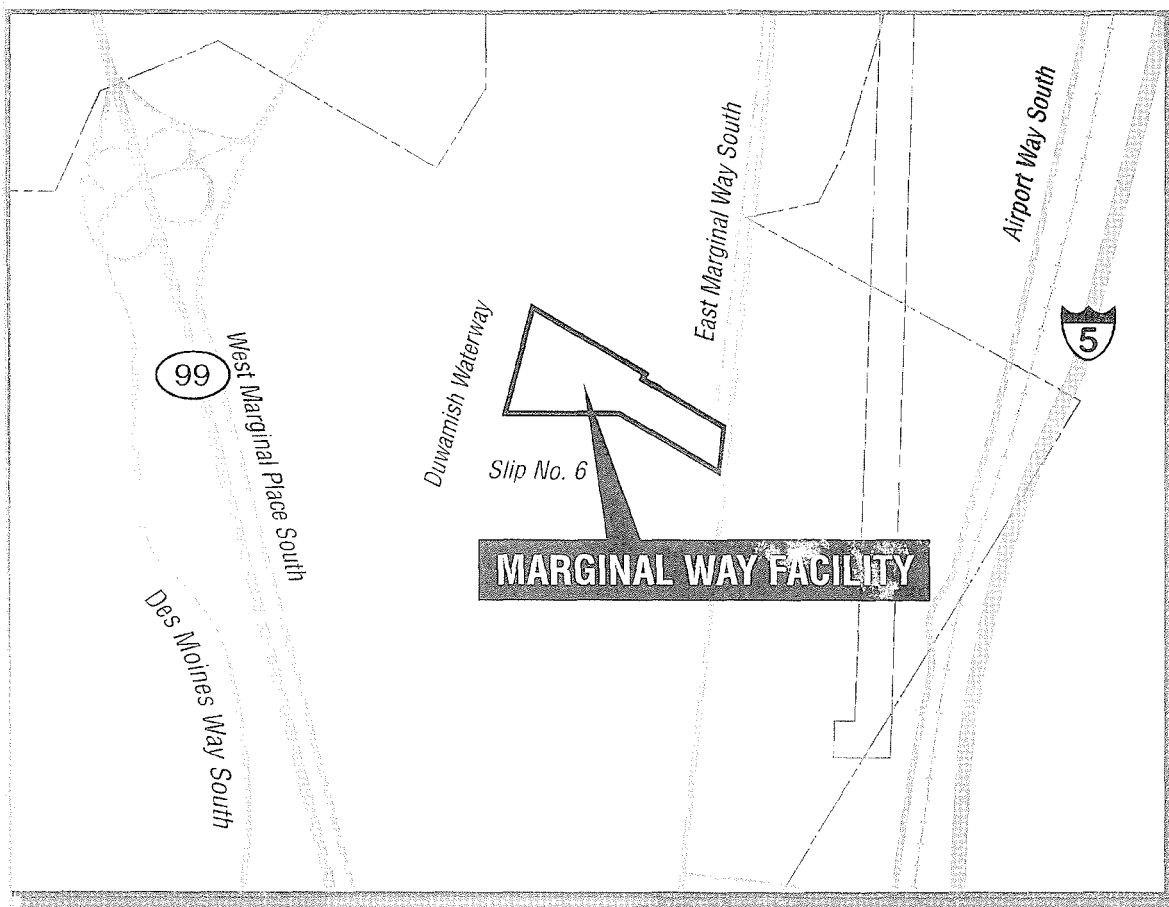


*Volume I: RFI Results and Conclusions*

# RCRA Facility Investigation (RFI) Report

*for the*

*Marginal Way Facility*     *Tukwila, Washington*



*Prepared for*

**U.S. Environmental Protection Agency, Region 10**

*Prepared by*  **RHÔNE-POULENC**

*in accordance with Administrative Order on Consent No. 1091-11-20-3008(h)*

*Draft - February 1995*



**RHÔNE-POULENC INC.**

CN 7500, CRANBURY, NJ 08512-7500  
TELEPHONE: (609) 860-4000

February 7, 1995

Mr. Tom Post  
U.S. EPA Project Coordinator  
U.S. EPA - Region 10  
1200 Sixth Avenue, HW-104  
Seattle, WA 98101

Subject: **Draft RCRA Facility Investigation Report  
Rhône-Poulenc's Tukwila, Washington Facility  
Administrative Order on Consent No. 1091-11-20-3008(b)**

Dear Mr. Post:

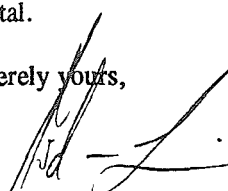
Enclosed please find two copies of the Draft RCRA Facility Investigation (RFI) Report for Rhône-Poulenc's Tukwila, Washington Facility. The RFI Report has been prepared in accordance with the requirements of Administrative Order on Consent No. 1091-11-20-3008(h), the RFI Workplan submitted on December 30, 1993 and the Addendum to the RFI Workplan submitted on July 25, 1994.

As required by the Consent Order, one copy of the report is also being sent to Byung Maeng of the Washington Department of Ecology.

I have also attached an agenda for the presentation of the RFI Report on February 17, 1994 at the Law Offices of Bogel & Gates, Two Union Square, 601 Union Street, from 9:00 a.m. to 1:00 p.m.

Should you have any questions, please call me at 609-860-3305. Again, I would like to thank you for granting Rhône-Poulenc an extension for this submittal.

Sincerely yours,



Edwin Liu  
Environmental Engineer

EL:jfo  
enclosures (3)  
95002

Cc: Byong Maeng/Washington Department of Ecology (one copy)

## **Agenda - Rhône-Poulenc Inc. RFI Presentation February 17, 1995**

- I.           Introductions and Project Roles
  
- II.          Objectives for Meeting
  - A.     RPI
  - B.     EPA
  - C.     Ecology
  
- III.        RFI Presentation
  - A.     Brief overview of report organization and contents
  - B.     Review of RFI Field Activities - Section 2
    - 1.     Round 1
    - 2.     Round 2
  - C.     Summary of RFI Results
  - D.     Conclusions
  
- IV.        Discuss Agency Questions on Report
  
- V.          Close Meeting

## Executive Summary

A RCRA Facility Investigation (RFI) was conducted at Rhône-Poulenc's Marginal Way Facility located in Tukwila, Washington. The RFI was conducted during the spring and summer of 1994 in accordance with conditions stipulated in Administrative Order on Consent No. 1091-11-20-3008(h) and the approved RFI Workplan (December 1993) and Addendum to the RFI Workplan (July 1994). The main objectives of the RFI were to:

- Characterize the environmental setting at the Facility.
- Determine the nature and extent of contamination from releases to soil, groundwater, sediments, or air at, or adjacent to, the Facility.
- Determine whether further actions are warranted and, in particular, whether a Corrective Measures Study (CMS) is warranted, based on a comparison of concentrations of detected constituents to action levels.

The overall objectives of the RFI were fulfilled through two rounds of field investigation and associated sampling, laboratory analysis, and data evaluation. The hydrogeologic characterization included the analysis of the Facility's hydrostratigraphy based on 73 borings drilled during the RFI. Groundwater elevations were monitored to evaluate groundwater flow conditions, "slug" tests were performed to estimate aquifer hydraulic conductivity, and physical property testing of soil was conducted to measure parameters such as moisture content, porosity, and hydraulic conductivity.

The RFI soil investigation consisted of surface and subsurface soil sampling in 10 soil investigation areas and a background area at the Facility. The soil samples were analyzed for a number of chemical constituents, including the preliminary constituents of concern identified in the RFI Workplan. The analytical results were compared to the Washington State Model Toxics Control Act (MTCA) Method C cleanup levels, the soil action levels for the RFI.

The RFI groundwater investigation consisted of the following activities:

- Groundwater samples were collected from the 30 pre-RFI monitoring wells during Round 1. These samples were analyzed for a wide range of parameters including inorganic compounds, volatile and semivolatile organic compounds, total organic carbon (TOC), formaldehyde, and Appendix IX constituents.
- Forty-three groundwater samples were collected from 29 borings during a HydroPunch survey. These samples were analyzed for volatile organic compounds, total petroleum hydrocarbons (TPH), and TOC.

- Groundwater samples were collected during Round 2 from eight new monitoring wells and 11 of the pre-RFI wells. These samples were analyzed for a selected group of constituents based on the Round 1 analytical results. The Round 2 constituents included toluene, total recoverable petroleum hydrocarbons (TRPH), acetone, methylphenol, bis(2)-chloroethylether, herbicides, antimony, beryllium, and vanadium.
- Constituents that were detected during these analyses were compared to their respective action levels. The action levels for groundwater were defined as the federal Maximum Contaminant Levels (MCLs) for drinking water.

The sediment investigation included two rounds of sampling and analysis from the shoreline along the intertidal zone of the Duwamish Waterway. The first round of sampling and analysis was conducted in accordance with the RFI Workplan. The second round was designed to comply with the Puget Sound Estuary Program protocols. Washington State Marine Sediment Management Standards were used as the primary action levels, and the analytical results were compared to these action levels during the RFI.

Other RFI activities included an ecological assessment of the Facility, an air emissions investigation, and fate and transport analyses. The fate and transport analyses included the use of two modeling techniques to estimate the potential for constituents of concern to reach surface water bodies through groundwater migration and discharge. The analyses also evaluated the effects of naturally occurring biodegradation.

Using the results of the RFI, including the Facility characterization and analytical results, the significant contamination factors that may pose risks to human health and/or the environment were identified. The major findings were as follows:

- **Hydrogeologic Conditions.** The hydrogeologic information collected during the RFI is generally consistent with the conclusions reached during previous Facility investigations. The Facility is underlain by two distinct aquifers separated by a low-permeability silt and clay stratum that is laterally continuous beneath the Facility and acts as an aquitard. Groundwater levels in both the Upper and Lower Aquifers are tidally influenced. The vertical hydraulic gradient between the Upper and Lower Aquifers is in the upward direction at all tide stages. This hydraulic condition and the low-permeability aquitard inhibit the downward migration of constituents from the Upper to the Lower Aquifer.

The net groundwater flow direction beneath the Facility is believed to be from east to west in both the Upper and Lower Aquifers. However, a groundwater extraction program being conducted at the Kenworth site, immediately north of the Facility, appears to be affecting flow conditions at the Facility. RFI data indicate that the net groundwater flow direction in the

Upper Aquifer, beneath the western portion of the Facility, is northward toward the Kenworth site when the extraction system is operating.

- **Soil.** With the exception of single detections of arsenic and mercury, action levels were not exceeded for soil; therefore, soil is not recommended for inclusion in a CMS. Arsenic and mercury are not considered to be constituents of concern because each constituent was detected only once above its action level; arsenic is known to be present regionally in soil; and during Round 2, a comprehensive investigation of potential mercury contamination demonstrated that the single detection above its action level was an isolated occurrence that could not be confirmed.
- **Groundwater Quality.** The results of the groundwater investigation indicate that toluene is the primary constituent of concern in groundwater. Other organic compounds were detected above action levels in the area of the toluene plume, but these constituents are considered of secondary concern because they are less widespread than the toluene and they do not exceed their action levels to the same degree as toluene. Only three metals (arsenic, beryllium, and chromium) were detected in filtered samples at concentrations exceeding action levels. Of these, arsenic and beryllium are not known to have been used at the Facility, and arsenic is known to be present regionally at high concentrations. Therefore, these two metals are not considered constituents of concern for the Facility. Chromium was detected above action levels in three samples; however, groundwater chemistry data indicate that chromium is present in the trivalent form and not the more toxic hexavalent form that the action level presumes. Light nonaqueous phase liquid (LNAPL) is currently not present in significant volumes beneath the Facility. Pre-RFI chemical characterization of the LNAPL indicates that it is composed primarily of non-toxic food-grade mineral oil. Although the groundwater action level for toluene has been exceeded, monitoring well data indicate that toluene has not migrated to the Duwamish Waterway or to any other offsite areas.
- **Fate and Transport Analyses.** Fate and transport analyses were conducted for several constituents of concern to evaluate the potential for discharge of contaminated groundwater to the Duwamish Waterway. The results of these analyses indicate that constituents of concern would not discharge to the Waterway at concentrations exceeding applicable surface water quality criteria. This is consistent with the fact that the toluene plume is not encroaching on the shoreline, and toluene is not discharging to the Duwamish Waterway. Further, a comparison of data collected over time (1986 to 1994) by Dames & Moore, Landau Associates, and Rhône-Poulenc indicates that the toluene plume is not migrating.

- **Sediments and Air.** The sediment sampling results indicate that constituents were not detected above regulatory criteria or surrounding industrial sediment levels. The air emissions sampling results show that constituents were detected at very low levels compared to applicable regulatory thresholds and ambient conditions. Therefore, sediments and air are not media of concern, do not appear to pose risks to human health or the environment, and do not warrant a CMS.

The following recommendations for future actions are made:

- A CMS is warranted for the toluene groundwater plume.
- The analysis of Facility-specific risks to human health and the environment will be completed when the Risk Assessment/Media Cleanup Standards evaluation is provided to U.S. EPA. Anthropogenic chemical constituents that do not have action levels but were detected in soil and groundwater will also be addressed in this analysis. The evaluation will be submitted 30 days after the final RFI Report.

sea1002A479.wp5

## CONTENTS

Executive Summary	ES-1
List of Abbreviations and Acronyms	iii
1 Introduction	1-1
1.1 Statement of Purpose	1-1
1.2 RCRA Action Levels	1-2
1.3 Organization of This RFI Report	1-3
2 Summary of RFI Fieldwork	2-1
2.1 Overall Technical Approach	2-3
2.1.1 Identification of Investigation Areas	2-3
2.1.2 Identification of Preliminary Constituents of Concern	2-3
2.2 Hydrogeologic Characterization	2-4
2.2.1 Soil and HydroPunch Borings and Monitoring Well Installation	2-4
2.2.2 Monitoring of Groundwater Elevations and Tidal Fluctuations	2-6
2.2.3 Hydraulic Conductivity Testing	2-7
2.2.4 Physical Property Testing	2-8
2.3 Soil Investigation	2-9
2.3.1 Soil Sampling Methods	2-10
2.3.2 Soil Sampling Locations in Areas A1, A3, A6, A8, A9, and A10	2-12
2.3.3 Soil Sampling Locations in Areas A2, A4, A5, A7, and BG	2-13
2.4 Groundwater Investigation	2-13
2.4.1 HydroPunch Investigation	2-14
2.4.2 Monitoring Well Sampling and Analysis	2-16
2.4.3 LNAPL Monitoring	2-19
2.5 Sediment Investigation	2-20
2.6 Ecological Site Assessment	2-21
2.7 Seep Assessment	2-22
2.8 Air Emissions Investigation	2-23
2.9 References	2-24
3 Field and Laboratory Quality Assurance/Quality Control	3-1
3.1 Field QA/QC	3-1
3.1.1 Soil Sampling QA/QC	3-1
3.1.2 Groundwater Sampling QA/QC	3-2
3.1.3 Sediment Sampling QA/QC	3-4
3.1.4 Air Emissions Sampling QA/QC	3-4



3.2	Laboratory QA/QC and Data Validation	3-5
3.2.1	Analytical Methodology and Laboratory QA/QC	3-5
3.2.2	Data Validation	3-6
3.2.3	Data Assessment	3-8
3.3	References	3-8
4	RFI Findings and Analytical Results	4-1
4.1	Hydrogeologic Characterization	4-2
4.1.1	Geology and Hydrostratigraphy	4-2
4.1.2	Groundwater Hydrology	4-5
4.2	Soil Investigation	4-18
4.2.1	Surface Soil Samples	4-20
4.2.2	Surface and Subsurface Soil Samples	4-26
4.2.3	Soil Investigation Summary	4-34
4.3	Groundwater Investigation	4-39
4.3.1	HydroPunch Results	4-39
4.3.2	Groundwater Monitoring Results	4-41
4.3.3	Extent of Toluene	4-44
4.3.4	LNAPL Occurrence	4-46
4.3.5	Miscellaneous Organic Compounds	4-48
4.3.6	Metals in Groundwater	4-51
4.3.7	Conventional Water Quality and Biological Indicator Parameters	4-53
4.3.8	Extent of Black Liquid	4-57
4.3.9	Groundwater Investigation Summary	4-57
4.4	Sediment Investigation	4-60
4.4.1	Sediment Investigation Results	4-61
4.4.2	Sediment Investigation Summary	4-64
4.5	Ecological Site Assessment	4-64
4.5.1	Facility Observations	4-65
4.5.2	Site Assessment Summary	4-66
4.6	Seep Assessment	4-66
4.7	Air Emissions Investigation	4-66
4.8	Fate and Transport of Constituents in Groundwater	4-67
4.8.1	Migration Rates of Constituents in Groundwater	4-67
4.8.2	Estimates of Constituent Concentrations in Groundwater	4-69
4.8.3	Summary of Fate and Transport Analyses	4-75
4.9	References	4-75
5	Conclusions and Recommendations	5-1
5.1	Conclusions	5-1
5.2	Recommendations for Future Actions	5-3

## LIST OF ABBREVIATIONS AND ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
AOC	Area of Concern
ARI	Analytical Resources Incorporated
ASIL	Acceptable Source Impact Level
ASTM	American Society for Testing Materials
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylene
CaCO <sub>3</sub>	calcium carbonate
CFR	Code of Federal Regulations
CGI	combustible gas indicator
CLP	Contract Laboratory Program
cm/sec	centimeters per second
CMS	Corrective Measures Study
CSO	combined sewer overflow
DO	dissolved oxygen
ft/day	feet per day
ft/ft	feet vertical/feet horizontal
gpm	gallons per minute
LNAPL	light nonaqueous phase liquid
MCL	Maximum Contaminant Level
MCS	Media Cleanup Standard
MCUL	Minimum Cleanup Level
MDL	method detection limit
meq/100g	milliequivalents per 100 grams
µg/kg	micrograms per kilogram
µg/l	micrograms per liter
mg/kg	milligrams per kilogram
ml	milliliter
ml/g	milliliters per gram
MTCA	Model Toxics Control Act
NGVD	National Geodetic Vertical Datum
OVM	organic vapor monitor
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PID	photoionization detector
ppbv	parts per billion by volume
ppm	parts per million
ppmv	parts per million by volume
PQL	practical quantitation limit
PSEP	Puget Sound Estuary Program
PVC	polyvinyl chloride

QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RPD	relative percent deviation
RPI	Rhône-Poulenc Inc.
SDG	sample delivery group
SQS	Sediment Quality Standards
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TDS	total dissolved solids
TLV	Threshold Limit Value
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TRPH	total recoverable petroleum hydrocarbons
USCS	Unified Soil Classification System
U.S. EPA	U.S. Environmental Protection Agency
VBL	vanillin black liquor
VOA	volatile organics analysis
WAC	Washington Administrative Code

1

INTRODUCTION

## **Section 1 Introduction**

### **1.1 Statement of Purpose**

On May 6, 1993, Rhône-Poulenc Inc. (RPI) and the U.S. Environmental Protection Agency Region 10 (U.S. EPA) entered into an Administrative Order on Consent (the Consent Order). The Consent Order, No. 1091-11-20-3008(h), specifies the Resource Conservation and Recovery Act (RCRA) corrective action requirements for RPI's Marginal Way Facility in Tukwila, Washington (the Facility), which include a RCRA Facility Investigation (RFI). This document, the draft RFI Report, is being submitted pursuant to Section VI.B of the Consent Order.

The general objectives of the RFI are to:

- Characterize the environmental setting at the Facility.
- Assess the nature and extent of contamination originating from releases of hazardous wastes and/or constituents from the Facility.
- Determine whether further actions are warranted, and in particular whether a Corrective Measures Study (CMS) is warranted, based on a comparison of concentrations of detected constituents to action levels.

The overall objectives of this draft RFI Report are to:

- Summarize the methods and procedures used to conduct the RFI.
- Present the findings and analytical results of the RFI, including the quality assurance and quality control (QA/QC) information supporting the data collected and analyzed.
- Present the conclusions of the RFI, including an assessment of the need for, and the scope of, a CMS.

Potential human health and environmental risks posed by hazardous wastes and/or constituents at the Facility will be addressed in the forthcoming Human Health and Ecological Risk Assessment Report and Proposed Media Cleanup Standards (MCSs) evaluation, which will be submitted 30 days after the final RFI Report, pursuant to Section VI.C of the Consent Order. The MCSs will be used during the CMS to evaluate potential remedial actions.

## 1.2 RCRA Action Levels

Attachment A to the Consent Order requires that the RFI Workplan process ". . . determine and develop action levels for constituents of concern in soil, groundwater, air, surface water, and sediments." This was done in discussions with U.S. EPA personnel during development of the RFI Workplan (approved by U.S. EPA on January 24, 1994), with the following action levels being identified for this RFI:

- For soil, Washington State Model Toxics Control Act (MTCA) Method C cleanup levels (WAC 173-340).
- For groundwater, federal Maximum Contaminant Levels (MCLs) for drinking water (40 CFR Parts 141 and 142).
- For sediments, Washington State Marine Sediment Management Standards (WAC 173-204).
- For fate and transport analyses, Washington State Water Quality Standards—Ambient Water Quality Criteria: Fresh Water (Chronic) (WAC 173-201) were used for comparative purposes. Other criteria, such as federal Water Quality Standards (40 CFR Part 131) and MTCA Method B cleanup levels for surface water (WAC 173-340) were used for comparison purposes for freshwater quality action levels.
- No formal action levels have been set for air emissions. However, the air emissions data are compared to (1) Threshold Limit Values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH) and (2) Acceptable Source Impact Levels (ASILs) established by the Washington State Department of Ecology.

In accordance with U.S. EPA guidance, these action levels reference promulgated health-based standards.

Action levels are often used in the RCRA corrective action process as "trigger mechanisms" to evaluate the need for a CMS; if no constituents are found at or above action levels in a given medium, a CMS may not be required for that medium. In this draft RFI Report, constituents detected during the RFI sampling and analysis will be compared to the action levels cited above. If action levels are exceeded, RPI will recommend that a CMS be conducted to further evaluate appropriate remedial actions for those constituents and media, consistent with current U.S. EPA guidance as presented in the final RCRA Corrective Action Plan (Directive 9902.3-2A, May 31, 1994). If constituents are not detected in a specific medium at concentrations above action levels, RPI will recommend that a CMS is not necessary for that medium.

### 1.3 Organization of This RFI Report

This RFI Report is organized into three documents, as follows:

- Volume I describes the overall technical approach to the RFI, the methods and procedures used for the RFI fieldwork, the RFI field and laboratory QA/QC procedures, the RFI findings and analytical results, the conclusions drawn from these findings and results, and recommendations for future actions.
- Volume II contains figures and tables illustrating and supplementing the information and data presented in Volume I.
- Volume III consists of appendices that provide additional information.

Following Section 1, the contents of Volume I are as follows:

- **Section 2, Summary of RFI Fieldwork.** Section 2 summarizes the overall technical approach to the RFI and the methods and procedures used to conduct the RFI fieldwork.
- **Section 3, Field and Laboratory Quality Assurance/Quality Control.** Section 3 presents the RFI QA/QC methodology and results.
- **Section 4, RFI Findings and Analytical Results.** Section 4 describes the analytical results and related findings of the RFI.
- **Section 5, Conclusions and Recommendations.** Section 5 presents the major conclusions of the RFI and recommendations for future actions, with emphasis on the significance of the RFI findings and results as they relate to the media and Facility areas that may require corrective measures.

sea1002A23D.wp5





## Section 2

### Summary of RFI Fieldwork

This section summarizes the methods and procedures used to conduct the RFI at RPI's Marginal Way Facility. The methods and procedures, along with the proposed scope of the initial field sampling and analysis, are described in detail in the RCRA Facility Investigation Workplan (RPI, December 1993). For reference purposes, the RFI Field Sampling Plan (Section 5 of the RFI Workplan) is included in this report as Appendix A.

As discussed in the RFI Workplan, an observational approach was used to implement the RFI. This was consistent with the phased approach anticipated in Attachment A of the Consent Order, which states:

A phased investigative approach is envisioned, with decision points that may eliminate the need or expand the scope for certain planned subsequent investigative or remedial phases.

In keeping with this approach, the field sampling and analysis associated with the RFI were performed in two "rounds" between January and September 1994. Round 1 was conducted in accordance with the RFI Workplan and took place from January to June 1994. Round 2 is described in the Addendum to the RFI Workplan (approved by U.S. EPA on July 1, 1994, and provided in this report as Appendix B), and was conducted in August and September 1994.

During the course of the RFI, some of the methods and procedures presented in the Workplan and the subsequent Addendum were modified. For the most part, the modifications were necessary to address the differences between conditions that were assumed and anticipated in the Workplan and the actual field conditions that were encountered during sampling activities. The modifications to the methods and procedures specified in the RFI Workplan and the Addendum have been documented and are presented in this report as Appendix C.

To evaluate the nature, extent, and related risks of Facility contamination, the RFI focused on investigating environmental media and assessing the potential for constituent transport to and from these media. Round 1 included the following activities:

- Hydrogeologic characterization of the Facility
- Soil sampling and analysis
- Groundwater sampling of all 30 pre-RFI monitoring wells (i.e., those installed during previous Facility investigations) and analysis of the samples collected

- A HydroPunch investigation to determine the extent of toluene in groundwater
- Monitoring of light nonaqueous phase liquid (LNAPL)
- Sediment sampling and analysis
- An ecological site assessment
- Inspections to detect seeps from the Facility into the Duwamish Waterway shoreline

Seep sampling and air emissions sampling were also initially planned for Round 1. For the reasons outlined in Section 2.7, seep sampling was not conducted during the RFI but is planned for March 1995. Air emissions sampling was postponed to Round 2 to permit sampling during warmer weather.

Round 2 consisted of a second RFI groundwater monitoring effort, additional soil and sediment sampling, air emissions sampling, and analysis of the samples collected. Specific Round 2 activities included:

- Drilling of seven soil borings in two investigation areas, collection of soil samples, and analysis for specific constituents
- Collection of shallow soil samples in one investigation area and analysis of the samples to confirm the presence of mercury detected during Round 1 and to evaluate its possible extent
- Installation of eight new monitoring wells in two investigation areas to enlarge the groundwater monitoring network in the vicinity of the toluene contamination investigated in Round 1
- A second round of groundwater sampling at 11 pre-RFI monitoring wells, and sampling of the eight new wells
- Measurements of LNAPL thickness in monitoring wells
- Collection of additional sediment samples in the intertidal zone along the Duwamish Waterway
- Air emissions sampling and analysis

The sections that follow describe the overall technical approach to the RFI, the hydrogeologic characterization of the site, and the fieldwork and analyses conducted for the specific environmental media investigations. These sections are:

- 2.1 – Overall Technical Approach
- 2.2 – Hydrogeologic Characterization
- 2.3 – Soil Investigation
- 2.4 – Groundwater Investigation
- 2.5 – Sediment Investigation
- 2.6 – Ecological Site Assessment
- 2.7 – Seep Assessment
- 2.8 – Air Emissions Investigation

All the RFI analytical data were entered into a project-specific database as the work progressed. A printout of detected constituents from this database is provided as Appendix D of this report.

## **2.1 Overall Technical Approach**

In order to provide the basis for the field investigation sampling and analysis plans, an overall technical approach was developed that took into consideration past Facility operations and specific RFI objectives for each environmental medium. The RFI Workplan describes this approach in detail. To reiterate RPI's overall investigative strategy, a summary of the approach is provided in the following two sections.

### **2.1.1 Identification of Investigation Areas**

The Facility was divided into 12 investigation areas, as shown in Figure 2-1. The primary purpose of identifying separate areas was to ensure an efficient Facility investigation that focused on areas of concern. The area designations group together locations at the Facility where similar operational and manufacturing activities occurred and where similar materials were used or handled. These designations also take into account information on Facility conditions obtained from previous investigations. A description of each investigation area was provided in the RFI Workplan, including a discussion of the chemicals formerly handled or used in the area and a summary of historical spills or incidents of record.

Specific sampling and analysis strategies were developed for each area, taking past Facility activities and environmental data into account, in order to characterize conditions related to soils, sediments, seeps, and surface water. The hydrogeologic characterization and groundwater investigation were implemented on a Facility-wide basis.

### **2.1.2 Identification of Preliminary Constituents of Concern**

The RFI Workplan identified preliminary chemical constituents of concern for each of the designated investigation areas at the Facility. These constituents were identified based on knowledge of past Facility operations and data collected during previous investigations by Dames & Moore (1986) and Landau Associates (1991). One of the objectives considered during the development of the sampling and analysis strategy was to confirm whether these

constituents are, in fact, present in environmental media in concentrations that exceed current action levels. Table 2-1 lists the preliminary constituents of concern by investigation area and environmental medium.

## **2.2 Hydrogeologic Characterization**

The conceptual hydrogeologic model of the Facility was well developed prior to the RFI. Therefore, the RFI hydrogeologic characterization focused on confirming and augmenting existing Facility information. Additional hydrogeologic information was collected during the RFI through the soil and HydroPunch investigations and during monitoring well installation.

As described in the RFI Workplan, the objectives of the RFI hydrogeologic characterization were to:

- Evaluate the thickness, areal extent, and permeability of the "perching layer" within the upper 10 to 15 feet of the subsurface. This was accomplished by logging the subsurface conditions at 73 borings drilled during the RFI.
- Confirm the lateral continuity and vertical permeability of the Aquitard separating the Upper and Lower Aquifers. This was accomplished by drilling six borings into the Aquitard.
- Evaluate the groundwater flow directions and gradients in the Upper and Lower Aquifers as influenced by the tidal fluctuations in the Duwamish Waterway. This was accomplished by monitoring groundwater elevations over multiple tidal cycles.
- Establish Facility-specific estimates for hydraulic conductivity. This was accomplished by conducting single-well hydraulic conductivity tests (slug tests).
- Measure selected physical properties of the geologic materials. This was accomplished by collecting soil samples and testing them for key physical characteristics, including grain size distribution, moisture content, specific gravity, porosity, hydraulic conductivity, bulk density, organic carbon content, and cation exchange capacity.

### **2.2.1 Soil and HydroPunch Borings and Monitoring Well Installation**

Seventy-three borings were drilled during the RFI to evaluate and define the Facility's hydrostratigraphy, collect soil and groundwater samples, and install monitoring wells. All borings were drilled with a hollow-stem auger drilling rig. During Round 1, 29 borings were drilled during the HydroPunch investigation and 29 additional borings were drilled for

soil sampling and hydrogeologic characterization purposes. Fifteen borings were drilled during Round 2, seven for soil sampling and eight for monitoring well installation. The borings ranged in depth from approximately 9 to 80 feet. The borehole diameters were 8 inches for the HydroPunch investigation and 10 inches for the monitoring wells. The locations of all the RFI borings are shown in Figure 2-2; the soil and HydroPunch boring logs are included in Appendix E, and the monitoring well geologic and construction logs are in Appendix F along with those for the pre-RFI monitoring wells.

During drilling, soil samples were collected for laboratory testing (chemical and physical analyses) and geologic logging purposes. The samples were collected using a 2-inch-outside-diameter (18 inches long) or a 3-inch-outside-diameter (18 inches long, extendable to 24 inches) split-spoon sampler driven by a 140-pound drop hammer. Samples were collected continuously in the Unsaturated Zone (from 0 to approximately 12 feet below ground surface [bgs]) and at 2.5-foot intervals below the groundwater table.

During Round 1, groundwater sampling was conducted in the 30 pre-RFI monitoring wells (shown in Figure 2-3). During Round 2, eight new wells were installed to confirm and monitor the horizontal and vertical distribution of the toluene plume and to provide additional locations for monitoring and detecting LNAPL. (Figure 2-4 shows the locations of these wells and the pre-RFI monitoring wells.) The placement of the new wells was based on the configuration of the toluene plume as identified by the results of the Round 1 HydroPunch investigation and groundwater samples collected from the pre-RFI monitoring wells in the immediate area (these results are presented in Section 4). Of the eight new wells, six (wells MW-14, -15, -17, -18, -19, and -20) were screened in the upper portion of the Upper Aquifer, across the groundwater table, and two (wells MW-13 and MW-16) were screened in the lower portion of the Upper Aquifer. The Round 2 monitoring wells were constructed of 4-inch-inside-diameter polyvinyl chloride (PVC) screen and casing. (All the pre-RFI wells are also constructed of 2-inch-inside-diameter PVC screen and casing except well MW-12, which is constructed of 4-inch-inside-diameter stainless-steel screen and casing.) A summary of the construction details for each of the eight wells and the 30 pre-RFI monitoring wells is provided in Table 2-2, and the well construction logs for all 38 wells are included in Appendix F.

All the soil and HydroPunch borings and Round 2 monitoring wells were surveyed for location and elevation during the RFI. The locations of all the borings and wells were surveyed to the nearest 0.1 foot. The elevations at ground surface of all the borings were surveyed to the nearest 0.1 foot; the elevations of the monitoring wells were surveyed to the nearest 0.01 foot (the well reference point is a notch inscribed at the top of the PVC well casing). The RFI survey data are provided as Appendix G of this report. The 30 pre-RFI monitoring wells were surveyed by CH2M HILL in 1993; the survey information for these older wells is also provided in Appendix G.

The horizontal data are based on an assumed coordinate system established specifically for the Facility. This assumed coordinate system can be tied to the State Plane Coordinate

System in the future, if required. Vertical control is referenced to the National Geodetic Vertical Datum (NGVD) of 1929.

### **2.2.2 Monitoring of Groundwater Elevations and Tidal Fluctuations**

Groundwater levels were measured in three ways during the RFI:

- A depth-to-groundwater measurement was made at each well when it was sampled, prior to well purging.
- Groundwater levels were measured manually at all 30 pre-RFI monitoring wells on five different occasions.
- From January 19 through February 15, 1994, groundwater levels in a network of 10 wells were continuously monitored and recorded at 15-minute intervals in order to assess tidally induced changes in groundwater flow directions and gradients. In addition, a stilling well installed in the Duwamish Waterway monitored tidal fluctuations.

With the exception of the 10-well network, all depth-to-groundwater measurements were collected manually using electronic water-level indicators.

#### ***Manual Groundwater-Level Monitoring***

Groundwater levels were measured manually at all 30 pre-RFI monitoring wells in February and June 1994. Readings were taken using Slope-Indicator electronic water-level indicators with the exception of well MW-12, where an ORS oil/water interface probe was used because of the presence of LNAPL in this well. All measurements were taken from the surveyed reference points at the top of the PVC well casings.

Groundwater levels were measured in the 30 pre-RFI monitoring wells four times on February 4, 1994, to coincide with the following tide stages estimated from tide charts for Seattle (Elliott Bay):

- Mid-tide rising at 7:26 a.m. (the measurement window was 6:56 a.m. to 7:56 a.m.)
- High tide at 10:24 a.m. (the measurement window was 9:54 a.m. to 10:54 a.m.)
- Mid-tide falling at 2:09 p.m. (the measurement window was 1:39 p.m. to 2:39 p.m.)
- Low tide at 5:55 p.m. (the measurement window was 5:25 p.m. to 6:25 p.m.)

In May 1994, RPI learned that Kenworth, Inc., the owner/operator of the property immediately north of the Facility, had been conducting groundwater remediation pursuant to a voluntary action under MTCA. This remediation effort had included groundwater extraction from three wells, located approximately 700 feet from RPI's property line, during February when the RFI groundwater levels were being measured. (Section 4.1.2 provides further discussion of the Kenworth groundwater extraction project.) To assess the potential effects of groundwater extraction at the Kenworth site on the measurement of groundwater levels at the RPI Facility, another round of groundwater-level measurements was conducted during high tide on June 23, 1994. This additional round of groundwater-level measurements was planned to correspond with a time when Kenworth was not pumping groundwater. High tide was at 6:52 p.m.; the measurement window was from 6:22 p.m. to 7:22 p.m.

### *Continuous Groundwater-Level Monitoring*

For the continuous groundwater-level monitoring program in January and February 1994, Geokon GC-3 dataloggers were connected to pressure-sensing transducers that were installed in 10 monitoring wells: wells B1A, H10, DM-1A, DM-2A, and DM-3A screened in the Upper Aquifer, and wells B1B, H1, DM-1B, DM-2B, and DM-3B screened in the Lower Aquifer (Figure 2-5). These were the only locations at the Facility where two monitoring wells were installed in the same place but in different aquifers (the Upper and Lower Aquifers or the upper and lower portions of the Upper Aquifer). Monitoring these well pairs simultaneously allowed assessment of the vertical and horizontal groundwater flow directions and gradients during multiple tide cycles.

The dataloggers were adjusted to collect readings at 15-minute intervals. In addition, groundwater levels in these wells were measured manually twice each week during the monitoring program to verify the accuracy of the data being recorded.

### **2.2.3 Hydraulic Conductivity Testing**

Field hydraulic conductivity tests (slug tests) have been conducted on 11 monitoring wells (Figure 2-6) to provide estimated hydraulic conductivity values for the Upper and Lower Aquifers. Five wells were tested on October 24, 1991, prior to the RFI; these tests were all conducted on Upper Aquifer wells to verify the appropriateness of a hydraulic conductivity assumption used in an Upper Aquifer groundwater extraction analysis completed by Landau Associates in 1991. During Round 1 of the RFI, six other wells were tested on April 22, 1994, to provide hydraulic conductivity data for additional locations in the Upper Aquifer and for wells screened in the Lower Aquifer.

Because the slug tests were conducted at different times and the field methods differed slightly, the two series of tests are described separately in the following two subsections.

### ***1991 Slug-Testing Methods***

In 1991, slug tests were performed on wells H10, H11, B2, B6, and DM-7. The groundwater in each well was displaced with a sealed and weighted 8-foot-long, 1-3/8-inch-diameter pipe or "slug." The slug was attached to monofilament line and lowered quickly into each well, and the recovery of the groundwater level (the falling head) was measured using a pressure-sensing transducer connected to an electronic datalogger. Well B2 was an exception; groundwater levels were measured manually using an electronic water-level indicator because the transducer and datalogger were being used at another well.

When the groundwater in the well recovered to the pre-test static level, the slug was rapidly removed and the groundwater level during the rising head portion of the test was measured and recorded by the datalogger (or the water-level indicator at well B2). To the extent possible, groundwater levels in the wells were also measured manually during each test with an electronic water-level indicator to provide backup and confirmatory data. All equipment lowered into a well was field-decontaminated after each use.

### ***1994 Slug-Testing Methods***

In 1994, slug tests were performed on three pairs of monitoring wells: DM-1A/DM-1B, DM-2A/DM-2B, and DM-3A/DM-3B. The groundwater in each well was displaced with a solid 7-foot-long, 1.5-inch-diameter acrylic rod. The slug was attached to monofilament line and lowered quickly into each well until fully submerged. Recovery of the groundwater level (the falling head) was measured using a pressure-sensing transducer connected to an electronic datalogger. When the groundwater level in the well recovered to the pre-test static level, the slug was rapidly removed and the groundwater level in the rising head portion of the test was measured.

Because of space constraints inside the 2-inch-inside-diameter well casing (a larger-diameter slug was used in 1994), it was not possible to manually monitor the groundwater levels with an electronic water-level indicator at the same time that the slug and the datalogging equipment were in the well. As with the 1991 testing, all equipment lowered into a well was field-decontaminated after each use.

#### **2.2.4 Physical Property Testing**

Soil samples were collected from the Unsaturated Zone, the Upper Aquifer, and the Aquitard between the Upper and Lower Aquifers and tested for selected physical properties to identify variations in lithology that may affect groundwater flow, to provide data for fate and transport analyses, and to collect information to evaluate alternative corrective measures and support treatability studies in the future, if deemed necessary.

Samples for physical property testing were collected during drilling operations, including the HydroPunch investigation and monitoring well installation. Bulk density and laboratory



hydraulic conductivity samples were collected using either a 3-inch-outside-diameter Shelby tube or a split-barrel ring sampler to provide relatively undisturbed samples.

The physical property testing was performed by Hong West & Associates of Lynnwood, Washington. One or more of the following tests were conducted on the 23 samples collected:

- Grain size distribution with hydrometer analysis as necessary (ASTM D422)
- Moisture content (ASTM D2216)
- Bulk density (ASTM D2937)
- Specific gravity (ASTM D854)
- Porosity (calculated from bulk density and specific gravity data)
- Laboratory hydraulic conductivity (ASTM D5084 or U.S. Army Corps of Engineers Laboratory Manual EM 1110-2-1906, Appendix VII, Section 5)
- Cation exchange capacity (Method SW9080)
- Total organic carbon (Method SW9060)

With the exception of the laboratory hydraulic conductivity testing, all the tests were conducted in accordance with the methods outlined in the approved RFI Workplan. Method ASTM D5084 (a flexible wall permeameter method) was used to determine hydraulic conductivity for all samples tested during Round 1. The above-referenced U.S. Army Corps of Engineers method was used for two samples collected during Round 2.

Table 2-3 shows the number of physical property tests performed by investigation area and hydrostratigraphic unit. The test results are summarized in Section 4 and provided in full in Appendix H.

## 2.3 Soil Investigation

The field methods for the RFI soil investigation were selected to meet the following objectives:

- Achieve an acceptable level of statistical confidence that the constituents of concern and the investigation areas and media at the Facility are accurately identified and characterized. This was accomplished by applying a nonparametric statistical method based on tolerance limits (Conover, 1980). In each investigation area, seven random soil samples were collected. The selected

tolerance limits provided a confidence that 85 percent of the time, 75 percent of the sampled area would be at or below the maximum concentration encountered. In combination with the results of the previous Facility investigations, the nature of possible soil contamination can then be more fully evaluated.

- Compare the concentrations of detected constituents to the action levels in order to assess the need for additional actions. This was accomplished by comparing the soil data to MTCA Method C cleanup levels.
- Identify the areas within each investigation area where constituent concentrations exceed their respective action levels. This was accomplished by estimating the size and geometry of soil "hot spots" using all available RFI data, including additional data collected during Round 2.
- Evaluate the potential for cross-media contamination from affected soil based on the results of the groundwater, sediment, and air emissions investigations. This was accomplished by assessing the type, magnitude, and vertical distribution of soil contamination relative to its proximity to groundwater and surface water and by conducting air sampling and analysis.

As described in Section 2.1 and in the approved RFI Workplan, the Facility was divided into 11 soil investigation areas for the purpose of assessing possible soil contamination. The investigation areas (Figure 2-1) were delineated according to their association with past Facility practices and historical analytical data. An independent sampling strategy was developed for each investigation area, as described later in this section.

Some soil sampling points shown in the RFI Workplan were located in areas where onsite obstructions or subsurface conditions precluded sampling. In these cases, alternate sampling points located nearby were chosen. These field modifications to the approved RFI Workplan are documented in the field logbooks and in Appendix C of this report.

Table 2-4 lists the soil investigation areas by name and number, cross-referenced to the Solid Waste Management Units (SWMUs) and Areas of Concern (AOCs) identified in the 1990 RCRA Facility Assessment (PRC Environmental Management, 1990). The laboratory analyses performed on samples from each investigation area are listed in Table 2-5. The soil sampling methods and locations are described in the following sections.

### **2.3.1 Soil Sampling Methods**

Two rounds of soil sampling were conducted during the RFI. Round 1 was conducted from January 17 to April 18, 1994, and Round 2 from August 3 to August 25, 1994. Laboratory analysis of the Round 1 soil samples was performed by ETC Laboratories in Redmond, Washington. ETC closed its Redmond laboratory in June 1994 when the firm merged with Pace Environmental and Coast-to-Coast Laboratories; laboratory analysis of

Round 2 soil samples was performed by Pace/Mid-Pacific Laboratories in Mountain View, California.

Round 1 sampling followed two general approaches. In investigation areas where only surface contamination was expected (Areas A1, A3, A6, A8, A9, and A10), surface soil samples were collected. In investigation areas where contaminants were suspected or known to be present at depth or where no historical data were available (Areas A2, A4, A5, A7, and BG), a surface sample was collected along with up to two additional subsurface samples. The number of samples obtained from each investigation area and their respective analyses are summarized in Table 2-6.

In Round 2, surface and subsurface soil samples (from the upper 2 feet below ground surface [bgs]) were collected for mercury analysis at 34 locations in Area A6. Round 2 also included drilling seven soil borings (up to 13 feet bgs) in Areas A4 and A5. Fifteen soil samples were obtained from the seven borings and were analyzed for toluene and total recoverable petroleum hydrocarbons (TRPH). The TRPH method (EPA Method 418.1) is an infrared spectroscopy technique for quantifying petroleum hydrocarbons. This method differs from the WTPH method used during Round 1 for quantifying TPH (Table 2-6). The TRPH analysis detects a broader range of petroleum hydrocarbons, including heavier oils and lubricants, and was deemed a more suitable method for evaluating the presence of mineral oil (Penetec oil) known to be present beneath a portion of the Facility.

In paved areas, the asphalt or concrete pavement was cut and removed and any underlying base-course material (commonly crushed rock) also removed. In unpaved areas, surficial grass, duff, or debris was removed to expose underlying soils. It should be noted that surface soil samples were collected from the first available soil encountered after removal of the asphalt or concrete pavement, debris, or grass from each location. Once the overburden was removed, the first 6 inches of soil were collected and analyzed as a surface soil sample. As a result, the surface soil depths shown in the RFI database (Appendix D) range up to 2 feet bgs, depending on the thickness of the overburden that was removed.

Surface soil samples were collected using a field-decontaminated stainless-steel spoon or scoop. Samples from greater depths were collected using standard hollow-stem auger drilling equipment and by driving field-decontaminated 3-inch-outside-diameter split-barrel samplers with a drop hammer.

In some cases, surface and subsurface conditions precluded collection of all the samples intended from a particular depth within a boring. Instances of no sample recovery are documented in the soil boring logs (Appendix E).

Split-barrel samples were collected continuously in the Unsaturated Zone. All the surface samples were sent to the laboratory for analysis; selection of the remaining (subsurface) samples for laboratory analysis depended on the headspace result for the surface sample at each boring. A portion of each sample was retained in a closed, resealable plastic bag, and a headspace analysis was conducted using a photoionization detector (PID) in order to

identify those samples likely to be most contaminated (the RFI Workplan called for the samples with the two highest PID readings to be analyzed). If the surface sample (i.e., from 0 to 0.5 foot bgs) had one of the highest PID readings, a second, subsurface sample was identified for analysis in addition to the surface sample. If the two highest PID readings came from the subsurface samples, these samples were sent for laboratory analysis along with the surface sample (i.e., a total of three samples were sent to the laboratory).

The portions of the samples used for headspace analysis, along with jarred samples not selected for laboratory analysis, were placed in drums with the drill cuttings following field screening in accordance with the RFI Workplan. The contents of the drums were subsequently sampled and analyzed; the disposition of these materials is currently being evaluated.

### **2.3.2 Soil Sampling Locations in Areas A1, A3, A6, A8, A9, and A10**

#### ***Round 1***

During Round 1, a minimum of seven surface soil samples were collected in each of the investigation areas A1, A3, A6, A8, A9, and A10. The sampling locations were established based on a random grid as specified in the RFI Workplan. The locations of the six areas are shown in Figure 2-1, and the sampling locations within each area are shown in Figures 2-7 through 2-12.

In Area A3, two additional shallow samples were collected near the former location of a compressor shed in order to evaluate whether polychlorinated biphenyls (PCBs) were present in soil because of possible oil leaks from the compressor.

Area A10 includes the process water and wastewater spill control sumps, API separators, and containment reservoir, which are located in different areas of the Facility. Instead of using a sampling grid, four random soil samples were collected from the outside perimeter of these five structures, for a total of 20 samples. Perimeter sample locations were determined by selecting a random starting point for the first sample location and then locating the remaining samples by dividing the perimeter distance by the number of samples to be collected (four).

#### ***Round 2***

During Round 2, 38 additional samples were collected for mercury analysis at 34 locations in Area A6 (see Figure 2-13). The additional mercury samples were collected in the immediate vicinity of Round 1 sampling locations A06-01 and A06-03 in order to confirm the presence and, if confirmed, to evaluate the extent of mercury reported at these locations during Round 1 sampling. The samples were collected from two depth intervals (0 to 0.5 foot and 1.5 to 2 feet bgs) at a grid interval of approximately 20 feet. However, four samples were located within 5 feet of sampling location A06-03, which yielded the sample with the highest Round 1 mercury concentration. With the exception of four samples

collected adjacent to sampling location A06-03, the subsurface samples were not analyzed by the laboratory because the results for all of the Round 2 surface samples did not indicate a mercury concentration above the MTCA Method C cleanup level (96 milligrams per kilogram [mg/kg]).

### 2.3.3 Soil Sampling Locations in Areas A2, A4, A5, A7, and BG

#### *Round 1*

Round 1 soil samples were obtained from the Unsaturated Zone (up to depths of approximately 9 to 12 feet) in Areas A2, A4, A7, and BG (the Background Area). The locations of these four areas are shown in Figure 2-1, and the sampling locations within each area are shown in Figures 2-14 through 2-17.

During Round 1, surface soil samples (from 0 to 0.5 foot bgs) were collected from seven locations in Area A5 (Figure 2-18). Deeper soil samples were collected from a total of seven borings drilled in Areas A4 and A5 during Round 2, as described below.

#### *Round 2*

Subsurface conditions encountered in Areas A4 and A5 during the Round 1 HydroPunch investigation indicated the possible presence of toluene in the Unsaturated Zone soil. Therefore, additional soil samples were collected during Round 2 from multiple depths within the Unsaturated Zone in Areas A4 and A5 (see borings A04-30 and A04-31 in Figure 2-15 and borings A05-10 through A05-14 in Figure 2-18).

## 2.4 Groundwater Investigation

The field methods for the RFI groundwater investigation were selected to meet the following objectives:

- Evaluate the general presence and distribution of constituents in groundwater across the Facility using the available monitoring well network, and confirm and augment the groundwater data collected by Dames & Moore (1986) and Landau Associates (1991). To accomplish these objectives, two rounds of groundwater monitoring were conducted at wells at the Facility.
- Compare the findings for detected constituents to the action levels in order to assess the need for additional actions. This was accomplished by comparing the groundwater data to federal Maximum Contaminant Levels (MCLs) for drinking water (40 CFR Parts 141 and 142).
- Investigate the presence and extent of toluene. This was accomplished with a HydroPunch investigation conducted in Areas A1, A4, A5, and A6, at or

near the locations where toluene was encountered in groundwater during previous investigations.

- Assess the distribution and identify the physical characteristics of the LNAPL. This was accomplished by monitoring for LNAPL at HydroPunch borings and Facility monitoring wells. In general, the detected volumes of LNAPL were so limited that collection of samples of sufficient quantity for physical property analyses was not possible. However, LNAPL physical property data are available from a sample collected in May 1993 from Landau Associates' monitoring well G5 (replaced in July 1993 by CH2M HILL's well MW-12).
- Investigate the presence of "Black Liquid" and evaluate whether toxic or regulated substances (e.g., chromium) are co-distributed with it. To accomplish these objectives, the extent of the liquid was identified during groundwater sampling, and wells containing the liquid were specifically evaluated for the potential co-distribution of toxic and regulated substances.

#### 2.4.1 HydroPunch Investigation

As part of the groundwater investigation, a HydroPunch investigation was conducted in Areas A1, A4, A5, and A6 during Round 1 of the RFI, between February 25 and April 14, 1994. The objectives were to assess the horizontal and vertical extent of LNAPL above the groundwater capillary fringe and evaluate the horizontal and vertical distribution of dissolved toluene. The HydroPunch investigation also facilitated the characterization of the Facility's hydrostratigraphy and the collection of soil samples for laboratory analysis (see Sections 2.1 and 2.2).

The Round 1 HydroPunch sampling locations are shown in Figure 2-19. The HydroPunch can be used in two different sampling modes depending on the intended sample media—LNAPL detection mode or groundwater mode. Both sampling modes were employed during the RFI, and they are described in the following two subsections.

##### *LNAPL Detection Mode*

In this mode, a borehole or pilot hole is drilled with a conventional hollow-stem auger drill rig to approximately 4 feet above the target sampling depth interval. The HydroPunch is then inserted into the borehole and driven to the sampling depth, exposing a screened sample chamber. The sample is collected from a bailer inserted into the chamber.

Soil was sampled continuously throughout the Unsaturated Zone at all HydroPunch boreholes, which facilitated visual identification of LNAPL. Because the HydroPunch can be used to detect floating product at the capillary fringe, it was always used in the LNAPL mode at the groundwater table. The depth selected for the first HydroPunch sample was estimated based on fluid-level measurements in the nearest monitoring well or recently-

completed boring. The depth interval was chosen so that the 4-foot-long HydroPunch screen spanned the groundwater capillary fringe when exposed. Prior to each use, the HydroPunch, the PVC screen, and the drive point were field-decontaminated by scrubbing them with Liquinox and water. Then they were steam-cleaned and rinsed with ASTM Type II water.

Upon reaching the top of the target depth interval, the HydroPunch was driven 4 feet ahead of the lead auger, and the outer sleeve of the HydroPunch was drawn back 3.5 feet to expose the screen to the formation. Typically, drilling was halted for 30 minutes to allow sufficient time for fluid recovery in the screened interval. A sample was then withdrawn from the HydroPunch using a laboratory-decontaminated, clear acrylic bailer lowered through the drilling rods from the ground surface.

If LNAPL was present in the bailer when it was recovered from the borehole, its thickness atop the water was measured and recorded. If no LNAPL was present, a sample of the recovered groundwater was collected for analysis. Prior to collection, an aliquot of the groundwater was tested for pH, conductivity, and temperature; a PID headspace measurement was also made of this sample. The remainder of the sample was then used to fill sample containers provided by the analytical laboratory. The containers were labeled and packed in chilled coolers in accordance with the approved RFI Workplan. The analytical methods for the HydroPunch groundwater samples are shown in Table 2-7.

In cases where LNAPL was present in the initial bailer sample, a groundwater sample was not collected. Instead, the borehole was advanced several more feet below the groundwater table so that a groundwater sample free from contact with LNAPL could be collected for analysis. This sample was collected using the HydroPunch in groundwater mode, described below.

### *Groundwater Mode*

In the groundwater mode, the HydroPunch is operated in much the same manner as the LNAPL mode and is used to collect groundwater samples from discrete depths. The HydroPunch is equipped with a 1,250-milliliter stainless-steel collection chamber with Viton check valves at each end (to minimize loss of sample), O-rings, a stainless-steel inlet screen, and a drive point. For the RFI, the inlet screens were decontaminated in the laboratory. All the other parts were decontaminated in the field using the following steps: scrubbing with Liquinox and tap water; rinsing with tap water, methanol, and ASTM Type II water; and air-drying. The body of the HydroPunch was decontaminated by steam-cleaning and rinsing with ASTM Type II water.

Before the HydroPunch was lowered down the hollow-stem auger, all drill rod joints were sealed with Teflon tape, and the bottom 3 feet of the HydroPunch were covered with a plastic bag and secured with a stainless-steel clamp to avoid the cross-contamination that might occur if the tool were to come in contact with LNAPL inside the auger. The HydroPunch was driven to a point approximately 3 feet ahead of the auger and then pulled back

approximately 1 foot to expose the inlet screen. Drilling was typically suspended for approximately 1 hour to allow time for the sample chamber to fill. When possible, the HydroPunch was left in place for longer periods (e.g., overnight). It was then withdrawn, the collection chamber was removed, and the groundwater sample was transferred into laboratory containers in accordance with the approved RFI Workplan.

The laboratory analyses performed on the collected samples included benzene, toluene, ethylbenzene, and xylene (BTEX) in rapid 24- to 48-hour turnaround time and total petroleum hydrocarbons (TPH) and total organic carbon (TOC) in standard turnaround time. Because of the limited capacity available within the chamber of the HydroPunch (1,250 ml), it was not possible to collect samples of sufficient quantity for field parameter analyses (pH, conductivity, and temperature).

The HydroPunch investigation proceeded with the drilling of a series of borings on approximately 50-foot centers in a north-south/east-west-oriented grid. This work began in Area A4, where LNAPL was known to be present and toluene concentrations in groundwater were high. The initial grid consisted of 13 locations within Area A4, as specified in the approved RFI Workplan. As the investigation progressed, HydroPunch locations were added in Areas A1, A5, and A6 for a total of 29 borings (see Figure 2-19). The additional locations were selected based on the presence or absence of LNAPL in nearby monitoring wells and in previously drilled HydroPunch borings; the laboratory toluene results for samples collected from HydroPunch borings drilled on previous days; and Round 1 groundwater quality data from nearby monitoring wells.

#### **2.4.2 Monitoring Well Sampling and Analysis**

Two rounds of groundwater sampling were conducted during the RFI. In Round 1, sampling was conducted at all 30 pre-RFI monitoring wells (Figure 2-3). In Round 2, sampling was conducted at 19 wells (Figure 2-20), 8 of which were installed during the Round 2 fieldwork.

Laboratory analysis of the Round 1 groundwater samples was performed by ETC Laboratories in Redmond, Washington. As noted in Section 2.3.1, ETC closed its Redmond laboratory in June 1994; laboratory analysis of Round 2 groundwater samples was performed by Pace/Mid-Pacific Laboratories in Mountain View, California.

#### ***Round 1***

Round 1 groundwater sampling was performed between January 17 and February 28, 1994. The 30 pre-RFI monitoring wells were sampled for one or more of the following constituent groups: the Appendix IX hazardous substances list, semivolatiles, volatiles, metals, formaldehyde, vanillin, isopropyl alcohol, general groundwater quality indicators (e.g., common ions and total dissolved solids), and selected biological activity indicators (phosphorus, nitrate, and total Kjeldahl nitrogen). Eight of the Round 1 wells representing different locations and depths were analyzed for the comprehensive Appendix IX analyte



list. Selection of the analytes for the remaining wells was based on the well locations and the previously identified constituents of concern. The RFI Workplan documents the rationale for the analytical program for groundwater samples. Table 2-8 lists the monitoring wells sampled in Round 1 and the analyses conducted for each well. The analytical methods for the Round 1 groundwater samples are listed in Table 2-9.

The activities involved in Round 1 groundwater sampling included measuring static groundwater elevations, purging wells, recording field parameters, and collecting samples. A brief summary of each activity follows.

**Groundwater Elevation Measurements.** Groundwater sampling was initiated at each well by unlocking the security cap and inspecting the well for damage and any needed repairs. The depth to the static groundwater level was then measured to the nearest 0.01 foot using a field-decontaminated electronic water-level indicator. If the well was known to have or suspected of having an LNAPL layer, an oil-water interface probe was used to measure the depth to LNAPL and to groundwater. Where LNAPL was detected, the groundwater elevation was corrected to account for the difference in specific gravity between the groundwater and LNAPL. The correction was made using the following equation:

$$W_c = W_m + [(L)(S_l/S_w)]$$

where:

$W_c$	=	Groundwater elevation (corrected)
$W_m$	=	Groundwater elevation (measured at LNAPL/groundwater interface)
$L$	=	LNAPL thickness
$S_l$	=	Specific gravity of LNAPL
$S_w$	=	Specific gravity of groundwater

The well number, depth to groundwater, time and date of measurement, total depth of the well, and length of the water column were recorded in the field logbooks.

**Well Purging.** Monitoring wells were purged prior to sampling by removing a minimum of three casing volumes of water using a laboratory-decontaminated stainless-steel bailer. Three wells, DM-7, H1, and B4, were purged using a Waterra sampling pump (a hand-operated, inertial, positive-displacement pump) because the PVC casing in these wells was misaligned and a bailer would not pass freely to the water in the well. The Waterra pumps were manufacturer-decontaminated and were employed as single-use, disposable purging and sampling pumps for these three wells.

**Field Parameter Measurements.** Temperature, pH, specific conductance, and the appearance of the purge water were recorded in the field notebook after each casing volume of water was purged. If the field parameter measurements made after the second and third casing volumes were within 10 percent of each other, the well was considered purged and

ready for sampling. If not, purging was continued until two consecutive casing volume field parameter measurements were within 10 percent. The total volume purged and the field parameters measured at each well were recorded in the field logbooks and are shown in Table 2-10.

During Round 1, purging in four wells either fell short of or exceeded the three casing volumes. Wells B6 and B2 were purged dry after 2 and 1.7 casing volumes, respectively. Field parameters measured in both wells were within 10 percent for the first and second volumes purged. Four casing volumes of water were purged from DM-6 because conductivity measurements varied by 14 percent between the second and third volumes purged. All field parameters measured between the third and fourth volumes purged were within 10 percent.

Purge water was collected in 55-gallon plastic drums and transferred to an onsite storage tank pending laboratory analysis. All purge water was subsequently discharged to the Metro sewer system after receipt of the analytical results.

**Groundwater Sample Collection.** Groundwater samples were collected from all the Round 1 wells using laboratory-decontaminated stainless-steel bailers, with the exception of wells DM-7, H1, and B4. These wells were sampled using Waterra pumps as described above.

Sampling personnel wore nitrile gloves during sample collection. Gloves were changed, at a minimum, between wells and whenever the potential for cross-contamination or other contamination was suspected.

Groundwater samples were collected in manufacturer-decontaminated, pre-labeled sample bottles. Samples collected for dissolved metals analysis were field-filtered through disposable Nalgene 0.45-micron filtration units prior to preservation to a pH level of <2 pH units with 1:1 nitric acid. Samples for total metals analysis were not filtered. The pH of each preserved dissolved metals sample was field-checked to ensure that the proper level of <2 pH units was achieved. Samples collected for volatiles, formaldehyde, and isopropyl alcohol analyses were collected into 40-ml volatile organics analysis (VOA) vials that were filled in such a way as to achieve minimal agitation and zero headspace.

After collection, all samples were placed into chilled coolers to maintain a temperature of 4°C for the duration of sampling and transporting. At the end of sampling each day, the identification numbers of samples collected that day were added to chain-of-custody forms, and the containers were repacked with additional ice for transport to the laboratory.

## ***Round 2***

Round 2 groundwater samples were collected between August 24 and September 1, 1994, from 19 monitoring wells whose locations are shown in Figure 2-20. Table 2-11 lists the analyses conducted for each well. The Addendum to the RFI Workplan (Appendix B of

this report) explains the rationale for the analytical program for Round 2 groundwater sampling. Round 2 groundwater sampling activities included measuring groundwater elevations, well purging, recording field parameters, and collecting samples. The primary difference in the groundwater sampling method during Round 2 compared to Round 1 was the use of dedicated Waterra pumps (described previously) to purge and sample all the wells. A brief summary of each Round 2 activity follows.

**Groundwater Elevation Measurements.** Initial inspection of each monitoring well and subsequent groundwater-level measurements were conducted as described under Round 1 above.

**Well Purging.** Monitoring wells were purged prior to sampling by removing a minimum of three casing volumes of water using manufacturer-decontaminated, single-use Waterra sampling pumps.

**Field Parameter Measurements.** The field parameters measured (Table 2-12) and the methods used were the same as those described under Round 1 above, with one addition. Dissolved oxygen (DO) was added as a field parameter for Round 2. DO was measured using a YSI model 51B meter and probe. The probe was lowered into the well until it was submerged in the screened depth interval. The probe was slowly moved up and down after each purge volume was removed. Readings were taken when the DO level stabilized. The probe and cable were field-decontaminated between wells by washing them with Liquinox and ASTM Type II water and rinsing them with ASTM Type II water.

Well purging exceeded three casing volumes in well H10. DO measurements varied by 60 percent between the second and third well volumes purged, but stabilized between the third and fourth volumes purged. Well H1 was purged dry after 1.6 casing volumes. Field parameters measured between the first and second purge volumes were within 10 percent.

**Groundwater Sample Collection.** All Round 2 groundwater samples were collected using manufacturer-decontaminated, dedicated, Waterra sampling pumps. Otherwise, the sampling protocols used during Round 2 were as described earlier for Round 1. At five of the wells (H1, MW-13, MW-17, MW-18, and MW-19), disposable polyethylene bailers were used to collect duplicate groundwater samples. This was done to evaluate potential differences in concentrations of volatiles reported for the two sampling methods; the data collected using Waterra pumps and bailers are discussed in Appendix I. The groundwater samples collected with the Waterra pumps are considered the samples of record for Round 2.

### 2.4.3 LNAPL Monitoring

During the RFI, LNAPL monitoring was conducted at regular intervals in pre-RFI monitoring wells. After the completion of Round 2, the eight new monitoring wells were also monitored for LNAPL. Measurements were made using an interface probe capable of measuring a thickness of less than one-hundredth of a foot or by collecting a liquid sample

from the well with a transparent bailer and visually inspecting the sample for LNAPL. When monitoring with this latter method, the bailer was carefully and slowly lowered partway through the air/fluid interface and then carefully withdrawn.

During March 1994, the LNAPL present in monitoring well H10 was measured and removed with a bailer at regular intervals. On March 23, a Model SOS-2 product skimmer manufactured by Clean Environment Equipment was installed in well H10. The skimmer consisted of a floating intake equipped with a hydrophobic membrane, which was controlled by a pneumatic pumping system and timer. By early April, no LNAPL was visibly accumulating in the well; the skimmer was operated until April 11, when it was removed because of diminishing LNAPL thickness and recovery volume. Monthly LNAPL monitoring and documentation are continuing at the Facility under Interim Measures status.

## 2.5 Sediment Investigation

The field methods for the RFI sediment investigation were selected to meet the following objectives:

- Assess the probability of sediment contamination in the investigation area along the Duwamish Waterway shoreline (Area A11). This was accomplished by applying a nonparametric statistical method outlined by Conover (1980), based on predetermined tolerance limits, to sediment sampling. The selected tolerance limits provided a confidence that 85 percent of the time, 75 percent of the sampled area will be at or below the maximum concentration encountered.
- Compare the findings for detected constituents to the action levels and define the boundaries of confirmed contamination in order to assess the need for additional actions. This was accomplished by comparing the sediment data to Washington State Marine Sediment Management Standards (WAC 173-204).

Sediment samples were collected from Area A11 during both rounds of the RFI. The first round of sampling was conducted on March 3, 1994, and the second round on August 18, 1994. Except as noted in this section, Round 1 sampling followed the approved RFI Workplan; however, sample analyses were not conducted specifically to comply with Puget Sound Estuary Program (PSEP) protocols. After consultation with the state Department of Ecology's Sediment Management Unit, the analytical methods were revised for Round 2 and documented in the Addendum to the RFI Workplan. The sampling locations are shown in Figure 2-21, and the analytical methods for both rounds of samples are listed in Table 2-13.

In both rounds, the samples were collected during low tide and the sampling locations were accessed by foot. The samples were collected using a field-decontaminated stainless-steel

scoop. Each sample was placed in a field-decontaminated stainless-steel bowl and mixed with the sampling scoop until visibly homogeneous. The homogeneous sample material was then transferred to laboratory-decontaminated, pre-labeled sample jars with Teflon-lined lids. All filled sample jars were stored in a chilled cooler at 4°C until delivered to the laboratory.

### ***Round 1***

During Round 1, the sediment samples collected from Area A11 were analyzed for semi-volatiles, pesticides/PCBs, metals, and total solids (a physical parameter). Laboratory analysis of Round 1 samples was conducted by ETC Laboratories in Redmond, Washington.

The Round 1 sampling points were located using Pathfinder mobile and base station global positioning equipment. The RFI Workplan specified that sediment samples would be obtained from the depth interval of 0 to 2 centimeters below the mudline. As documented in Appendix C, the Round 1 samples were inadvertently obtained from the depth interval of 0 to 0.5 foot below the mudline. However, the analytical results are useful for comparison with previous sediment sampling conducted by Landau Associates (1991), as the 0- to 0.5-foot depth interval corresponds to the sampling interval chosen by Landau.

### ***Round 2***

During Round 2, sediment samples collected from Area A11 were analyzed for volatiles, semivolatiles, pesticides/PCBs, metals, total organic carbon, sulfide, ammonia, pH, and physical parameters (total solids, grain size, and specific gravity). Round 2 analytes were selected so that the results could be compared with Marine Sediment Management Standards.

Round 2 sediment samples were collected from a depth of 0 to 2 centimeters as specified in the RFI Workplan. Round 2 sampling procedures corresponded to the PSEP protocols. An onshore surveyor was used to position field personnel within 5 feet of the Round 1 sampling stations.

As noted in Sections 2.3.1 and 2.4.2, ETC closed its Redmond laboratory in June 1994. Laboratory analysis of Round 2 sediment samples was performed by Analytical Resources, Inc., of Seattle, Washington. Analysis of the physical parameters grain size and specific gravity was conducted by Soil Technology of Bainbridge Island, Washington.

## **2.6 Ecological Site Assessment**

On August 18, 1994, an ecological assessment of the Facility was conducted in order to qualitatively identify plants and animals that are found onsite and to assess possible effects from hazardous substances currently under investigation.

The Facility consists of two distinct parts: the upland industrial area, which comprises approximately 19.5 acres above the east bank of the Duwamish Waterway, and the shoreline area, which extends from the top of the Waterway bank approximately 165 feet west into the intertidal portion of the Waterway channel.

The ecological assessment was performed by inspecting the upland portion of the Facility and walking along the shoreline area (north and south) of the Duwamish Waterway and west into the Waterway during low tide, along a distance of approximately 90 feet. Activities included observing physical site characteristics and habitat potential, identifying plants and animals, interviewing personnel who have worked at the Facility, and documenting observations of the conditions of the habitat and species encountered. The assessment was conducted in general accordance with U.S. EPA's guidance document *Ecological Assessment of Superfund Sites: An Overview* (1991).

## 2.7 Seep Assessment

As described in the RFI Workplan, seep sampling was planned for the RFI to assess the quality of groundwater discharging to the Duwamish Waterway and to evaluate the potential for cross-media contamination from groundwater to surface water and sediments.

Prior to and during Round 1 of the RFI, several inspections were made of the riprap and intertidal zone along the Duwamish Waterway in an attempt to locate seeps that could be sampled. The inspections were made during the winter, spring, and summer: on June 6 and December 9, 1993, and January 5 and March 3, 1994. No seeps were observed during any of these inspections.

However, during the Round 2 sediment sampling event, which was conducted during a minus-1-foot tide on August 18, 1994, field personnel were able to walk farther out on the soft intertidal sediments than during previous visits. With the extended vantage point, they observed a lightly flowing clear seep below the riprap along the base of the riverbank near the southwest corner of the Facility. This seep is not visible from the bank or the shoreline during average tides.

Seep sampling was not performed during that site visit because the tide window was limited, prepared laboratory containers were not available, and engineering controls to accumulate and collect seep water (e.g., a notched weir) would have been necessary to collect the volume needed for Appendix IX hazardous substance list samples (as specified in the RFI Workplan). Because sediment sampling takes place in the intertidal zone, sampling of this seep is planned for a minus-tide event that occurs during daylight hours on March 20, 1995. On that day, a tide of minus-0.4 foot is indicated for 1:13 p.m.

As described in the RFI Workplan, the seep sample will be analyzed for selected inorganics (metals and ions), volatiles, semivolatiles, and formaldehyde. The results of the seep sampling and analysis will be presented as an addendum to this RFI Report.

## 2.8 Air Emissions Investigation

The field methods used to evaluate air quality at the Facility were selected to meet the objectives of the RFI air emissions investigation, which included:

- Evaluate existing Facility conditions and assess the potential for air releases.
- Determine the source(s) of any air contaminants onsite.
- Evaluate the physical processes that may emit air contaminants.
- Assess the significance of any emissions and their potential for impacts.

Based on Facility visits by CH2M HILL air quality specialists, it was determined that potential sources of air contaminants existed onsite in two investigation areas, A4 and A8. Area A4 includes an area of known toluene contamination of groundwater and soil; Area A8 is the site of a former maintenance facility where volatile materials were previously used and reportedly disposed of.

On August 11, 1994, during Round 2 of the RFI, soil vapor samples were collected using a flux chamber. The samples were collected in Area A4 and in Area A8 at the west end of the old maintenance shop. The locations of the samples are shown in Figure 2-22.

The air sampling procedures followed the approved RFI Workplan. Soil at the A04-AM-01 location was covered with asphalt paving. In order to access the soil, a 2-foot-diameter opening in the asphalt was cut using a drill rig equipped with an asphalt-cutting bit. The flux chamber was immediately placed on the exposed soil surface. Organic vapor monitor (OVM) readings were taken at 15-second intervals for the first 7 minutes of the test and then at 30-second intervals until no change in concentration was observed (approximately 30 minutes into the testing). After air emissions from the soil stabilized, two air samples were collected in stainless-steel canisters.

At the A08-AM-01 sampling location, an OVM with a PID was used for real-time measurements of concentrations of volatile organic compounds emitted from the soil over time. The flux chamber was placed on the exposed soil surface, and OVM readings were taken at 15-second intervals for the first 7 minutes of the test and then at 30-second intervals until no change in concentration was observed (approximately 30 minutes into the testing). After air emissions from the soil stabilized, two samples were collected in stainless-steel canisters.

A total of four air samples were collected and analyzed for acetone, methylene chloride, benzene, and toluene. Table 2-14 summarizes the information concerning the samples collected.

## 2.9 References

Conover, W. J. *Practical Nonparametric Statistics*. Second Edition. John Wiley & Sons, New York, New York, 1980.

Dames & Moore. *Phase II, Site Screening Investigation, Final Report*. Prepared for Rhône-Poulenc Inc., Seattle, Washington, October 1986.

Landau Associates, Inc. *Site Assessment, Rhône-Poulenc Facility, Tukwila, Washington*. Prepared for Boeing Environmental Affairs, Seattle, Washington, September 1991.

PRC Environmental Management, Inc. *Rhône-Poulenc Inc., Marginal Way Facility, Seattle, Washington, RCRA Facility Assessment, Final Report*. Prepared for U.S. Environmental Protection Agency, Office of Waste Programs Enforcement, Washington, D.C., March 1990.

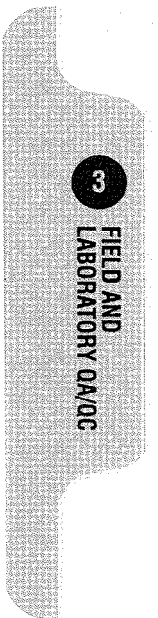
Rhône-Poulenc Inc. *RCRA Facility Investigation Workplan for the Marginal Way Facility, Tukwila, Washington*. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington, December 1993.

Rhône-Poulenc Inc. *Addendum to the RCRA Facility Investigation (RFI) Workplan for the Marginal Way Facility, Tukwila, Washington*. Prepared for U.S. Environmental Protection Agency Region 10, Seattle, Washington, July 1994.

U.S. Environmental Protection Agency. *Ecological Assessment of Superfund Sites: An Overview*. Publication No. 9345.0.51, December 1991.

sea1002A465.wp5





### Section 3

## Field and Laboratory Quality Assurance/ Quality Control

The RFI Quality Assurance/Quality Control (QA/QC) procedures were established to provide data of known quality and allow evaluation and understanding of ongoing data collection efforts, as well as to draw better relationships and comparisons with previous studies conducted at the Facility (i.e., Dames & Moore, 1986, and Landau Associates, 1991).

### 3.1 Field QA/QC

The following sections discuss the field QA/QC procedures implemented for the RFI soil, groundwater, HydroPunch, sediment, and air emissions sampling and groundwater-level monitoring.

#### 3.1.1 Soil Sampling QA/QC

QA/QC samples were collected during soil sampling to evaluate the contamination introduced by sampling equipment or sample collection methods. Contamination introduced by sampling equipment or methods was evaluated by equipment blanks, which were collected as part of the field QA/QC program. The equipment blanks were collected following the procedures specified in Section 5.5 of the approved RFI Workplan (included in this report as Appendix A), with the exceptions listed in Appendix C of this report.

Fourteen equipment blanks were collected during the Round 1 soil investigation. The only contaminants detected in the Round 1 equipment blanks were low levels of metals, acetone, bis(2-ethylhexyl)phthalate, and methylene chloride. These compounds are common contaminants; acetone and methylene chloride are common solvents found in field and laboratory operations; phthalates are introduced from polymeric plasticizers such as those found on tubing in the field and the laboratory; low levels of metals are naturally found in water used for rinsing equipment.

During Round 2 sampling, two equipment blanks were collected and analyzed. Toluene was detected in one of the samples at 9.6 micrograms per liter ( $\mu\text{g/l}$ ), but this did not impact decisions regarding toluene detections in field samples because toluene was already a constituent of concern due to previous detection at the Facility.

### 3.1.2 Groundwater Sampling QA/QC

#### *Monitoring Well Sampling*

QA/QC procedures were implemented during groundwater sampling of monitoring wells to evaluate the following:

- Variation and precision in the overall methodology
- Contamination introduced by sampling equipment or sample collection methods
- Sample contamination from ambient conditions

The first data collection step taken during groundwater sampling was measurement of the depth to groundwater in the well. QA/QC procedures were implemented during groundwater-level monitoring in order to collect accurate data, to eliminate measurement and transcription errors, and to minimize the potential for lost data. The following groundwater-level measurement QA/QC procedures were implemented:

- Equipment calibration. The accuracy of the groundwater-level meter probe and the measurement scale was checked with a tape measure prior to use. Discrepancies were recorded in the field logbooks.
- Duplicate water-level measurements. Each groundwater-level measurement was checked twice, at a minimum, while the measurement was being made.
- Data checks for anomalous values. Depth-to-groundwater data were checked in the field and in the office for anomalous values. If anomalous values were found, the field notes were checked for transcription errors.

Three types of samples were collected as part of the RFI groundwater field QA/QC program: field duplicates, equipment blanks, and trip blanks. The QA/QC samples followed the procedures specified in Section 5.5 of the approved RFI Workplan (Appendix A in this report), with the exceptions listed in Appendix C of this report.

Variation and precision in the overall methodology were evaluated by field duplicate analysis. The Round 1 field duplicate sample results are presented in Tables 3-1 through 3-3, and the Round 2 duplicate sample results are presented in Table 3-4. The reported results are average values of the duplicate samples. In cases where one sample was detected and the duplicate sample was a nondetection (or vice versa), one-half of the detection limit was used to calculate the sample result. Relative percent deviation values (RPDs) for the duplicate results are listed in Tables 3-1 through 3-4. These values give an overall indication of the variability of the detected concentrations.

Contamination introduced by sampling equipment or sample collection methods were evaluated by equipment blanks. Four equipment blanks were collected. Constituents found in the equipment blanks included metals, methylene chloride, formaldehyde, and bis-(2-ethylhexyl)phthalate; low levels of metals are naturally found in water used for rinsing equipment; methylene chloride is a common solvent found in the field and laboratory operations; bis(2-ethylhexyl)phthalate is a common plasticizer found in the field and laboratory materials. The results of the equipment blanks are presented in Appendix D. For samples that show detected constituents corresponding to the blanks, the sample results have been qualified following U.S. EPA guidelines. The equipment blank results are in alignment with the contamination levels generally encountered in these studies and do not interfere with the interpretation of the results or the final conclusions.

Sample contamination from ambient conditions was evaluated by trip blanks. Detections found in trip blanks help establish sources of contamination; contamination of trip blanks by compounds not detected in laboratory blanks is an indication of contamination introduced during transport by diffusion across samples or from ambient air. Ten trip blanks were collected during Round 1. Constituents found in the trip blanks included toluene and methylene chloride. The concentrations in the Round 1 sample results have been corrected based on trip blank contaminations, following U.S. EPA guidelines. No target compounds were detected in the three trip blanks collected during Round 2.

### *HydroPunch Sampling*

QA/QC samples were collected during HydroPunch groundwater sampling to evaluate the following:

- Contamination introduced by sampling equipment or methods
- Sample contamination from ambient conditions

Two types of samples were collected as part of the RFI field QA/QC program: equipment blanks and trip blanks. The QA/QC samples were taken following the procedures specified in Section 5.5 of the approved RFI Workplan (Appendix A in this report), with the exceptions listed in Appendix C of this report.

Contamination introduced by sampling equipment or methods was evaluated by equipment blanks. Four equipment blanks were collected. Contaminants were not detected in the equipment blanks.

Sample contamination from ambient conditions was evaluated by trip blanks. Two trip blanks were collected. Contaminants were not detected in the trip blanks.

### 3.1.3 Sediment Sampling QA/QC

QA/QC samples were collected during sediment sampling to evaluate the following:

- Variation and precision in the overall methodology
- Contamination introduced by sampling equipment or methods

Two types of samples were collected as part of the RFI field QA/QC program: field duplicates and equipment blanks. The QA/QC samples were taken following the procedures specified in Section 5.5 of the approved RFI Workplan (Appendix A in this report), with the exceptions listed in Appendix C of this report.

Variation and precision in the overall methodology were evaluated by field duplicate analysis. The Round 1 duplicate sample results are presented in Table 3-5, and the Round 2 duplicate sample results are presented in Table 3-6. The reported results are average values of the duplicate samples. In cases where one sample was detected and the duplicate sample was a nondetection (or vice versa), one-half of the detection limit was used to calculate the sample concentration. RPDs for the duplicate results are listed in Tables 3-5 and 3-6. These values give an overall indication of the variability of the detected concentrations.

Contamination introduced by sampling equipment or methods was evaluated by equipment blanks. One equipment blank was collected during Round 1 sediment sampling. Contaminants found in the equipment blank included low levels of metals naturally found in rinsate water and possibly introduced by the stainless-steel equipment.

### 3.1.4 Air Emissions Sampling QA/QC

As specified in the approved RFI Workplan, samples were collected in duplicate: the equipment blank was collected first, and then the first sample was collected. The second sample was collected within two minutes of the first sample.

As shown in Table 3-7, the detected value in the equipment blank for acetone was lower than the sample results, which ranged from 3.4 parts per billion by volume (ppbv) to 9.3 ppbv. The equipment blank's toluene result was higher than any of the subsequent sample results. If blank subtraction were performed for these analytes, the sample results would be insignificant—low to not detectable. To be conservative, blank subtraction was not performed.

Variation and precision in the overall methodology were evaluated by field duplicates. The field duplicate RPDs for samples 02-F2-FC and 03-F2-FC ranged from 9 to 15 percent. The RPDs for samples 04-H11-FC and 05-H11-FC (collected at location A04-AM-01) ranged from 3 to 93 percent. Since the asphalt was removed from this latter location and dissipation of volatile constituents was noted with the OVM at ppbv levels, it is likely that this dissipation continued to occur over the time of sample collection for these ppbv levels.

Therefore, the samples are not true duplicates; instead, they show the dissipation of volatile organic material with time at this freshly exposed area of soil.

### 3.2 Laboratory QA/QC and Data Validation

The following sections discuss the laboratory QA/QC and data validation procedures implemented for the RFI soil, groundwater, sediment, and air emissions samples, and present an assessment of the validated data.

#### 3.2.1 Analytical Methodology and Laboratory QA/QC

Soil, water, and sediment samples conducted during the RFI fieldwork were analyzed using the analytical methodologies detailed in the approved RFI Workplan (Section 6 and Appendix G). Pertinent portions of the methodologies are summarized below and in Table 3-8 for soil analyses, Table 3-9 for water analyses, and Table 3-10 for sediment analyses.

Appendix IX hazardous substance list parameters, as identified in 40 CFR 261, were analyzed following the U.S. EPA Statement of Work, *Test Methods for Evaluating Solid Waste*, methodology SW-846, for comparability to other RCRA studies. In order to ensure data of known quality and to follow the fundamental SW-846 methodology (i.e., sample preparation, instrument parameters, detection limits, etc.), U.S. EPA Contract Laboratory Program (CLP) QC protocols were implemented for analyses of volatiles, semivolatiles, pesticides/PCBs, and metals. The CLP QC was specified in the laboratory statement of work. While SW-846 QC specifications constitute guidelines only and allow for variability among different laboratories, the CLP QC is more specific in providing comparable data of known quality: the CLP gives detailed descriptions of QC procedures, levels of effort, frequency of runs, and acceptable limits.

For those Appendix IX hazardous substance list parameters that are not included under CLP protocols (e.g., herbicides, organophosphorus pesticides, and sulfide), QC specifications were established for this RFI at levels equivalent to U.S. EPA CLP protocols (see the RFI Workplan, Section 6 and Appendix G); for every QC check, the specific procedure, level of effort, and acceptance limits along with corrective action requirements were detailed. The project specifications included detection limits, calibration procedures and criteria, internal quality control checks and corrective actions, data calculations and reporting units, documentation, and deliverable items.

Geotechnical parameters were analyzed per standard ASTM methods and are listed in Table 3-8. Analysis of water quality parameters (anions, cations, and nutrients) and treatability parameters followed standard U.S. EPA methodology, as noted in Table 3-9. As these parameters are not covered under the CLP, QC specifications were established at a comparable level.

Round 2 sediment samples were analyzed following Puget Sound Estuary Program protocols or standard U.S. EPA methodology, as noted in Table 3-10. CLP protocols and CLP QC requirements were specified where applicable. For parameters not covered under the CLP, QC specifications were established at a comparable level (see the RFI Workplan, Section 6 and Appendix G).

Project target detection limit specifications are presented in Tables 3-8, 3-9, and 3-10 and follow RCRA guidelines. U.S. EPA SW-846-specified practical quantitation limits (PQLs) were met where applicable. For parameters where no PQLs are defined, appropriate project-specific target detection limits were identified in the laboratory statement of work. SW-846 also specifies establishing laboratory-specific Method Detection Limits (MDLs) per 40 CFR Part 163, Appendix B; the laboratories have established MDLs following this procedure. The laboratory MDLs for this project are below their respective PQLs. Suggested action levels, such as maximum contaminant levels (MCLs) for groundwater, MTCA Method C cleanup levels for soil, and existing regulatory limits for sediments (state Marine Sediment Management Standards), were met for most parameters, except in the cases where PQLs are above the proposed action levels and when dilution was necessary because of matrix interference or high sample concentration.

It should be noted that Round 1 groundwater samples analyzed for herbicides (U.S. EPA Method 8150) were rejected based on spike percent recoveries outside the acceptance criteria. As a result, herbicide samples were collected and analyzed again during Round 2. These data were determined to be acceptable and are included in the RFI database (Appendix D); the Round 1 herbicide data are not included in the database and were not used in any way during the RFI.

The laboratory selected to carry out the Round 1 analyses was ETC Northwest, located in Redmond, Washington. ETC Northwest was audited for SW-846 and CLP capability as well as State of Washington certification. The analyses of physical properties for soil were carried out by Hong West & Associates located in Lynnwood, Washington.

Because of the unanticipated laboratory closure of ETC Northwest (see Section 2.3.1), the Round 2 analyses were performed by Pace/Mid-Pacific Laboratory located in Mountain View, California. Pace/Mid-Pacific was also audited for SW-846 and CLP capability.

Round 2 sediment analyses were performed by Analytical Resources Incorporated (ARI) located in Seattle, Washington. ARI is certified to perform analyses under the Puget Sound Estuary Program. Sediment physical property analyses, which included grain size and specific gravity, were performed by Soil Technology Laboratory located in Seattle, Washington.

### 3.2.2 Data Validation

For parameters covered by the CLP, data validation followed the U.S. EPA *National Functional Guidelines for Organic Data Review* (1991) and *Functional Guidelines for Evaluating*

*Inorganic Analysis* (1988). For parameters not covered by the CLP, data validation followed the Quality Assurance Project Plan (QAPP) in the approved RFI Workplan.

The analytical laboratory managed and tracked samples in sample delivery groups (SDGs); the samples in an SDG had common QC data, as they were run consecutively. When the analytical laboratory reports were received by RPI, separate data review reports were prepared for each individual sample delivery group. For approximately 10 percent of the SDGs, each report was prepared following procedures and subsection headings for the full CLP review as defined in the U.S. EPA functional guidelines; this included raw data checks following EPA guidelines. For the remainder of the SDGs a summary report was prepared by reviewing all QC summary data, following procedures defined in the U.S. EPA functional guidelines. Tables 3-11 and 3-12 summarize the levels of data validation conducted for all SDGs in Rounds 1 and 2. Both types of reports were prepared following U.S. EPA guidelines to include checks for proper methodology, the level of QC effort (the frequency of runs), conformance to U.S. EPA-defined quantitative control limits, and details of analytical protocol deviations, if any.

All the reports summarize the data that did not meet QA/QC requirements, if any, with the following minimum information:

- The affected sample numbers
- The affected parameters
- The specific quantitative deviation from the QC requirements
- A description of the data validation flag, whether it was caused by laboratory error (designated as a "protocol" flag) or by matrix, analytical, or instrument limitations (designated as an "advisory" flag)

The data validation flags and their meanings are as follows:

- U The concentration is less than the listed value (not detected).
- J The estimated value is for qualitative use only.
- R The data are restricted and may not be used for any purpose.
- UJ The concentration is less than the estimated detection limit; the detection limit should be used qualitatively and may bias the result to a false negative.

The data flags caused by analytical protocol deviations are presented in the database. Additional data-reporting qualifiers originating from the laboratory were received in the electronic data reports and hardcopy reports. These qualifiers are procedural in nature and



may or may not address data quality. A list of these data-reporting qualifiers and their meanings is included in Appendix D of this report, together with a complete set of detected chemicals.

Qualification of sample analyses for contamination observed in laboratory blank samples was detailed in the data validation reports. In the individual validation reports, a significant number of volatiles were reported. These samples were corrected for laboratory contamination following U.S. EPA guidelines, and the qualifications have been incorporated into the data used in this report.

### 3.2.3 Data Assessment

The validated data have met and exceeded the project Quality Assurance goals described in the QAPP in the approved RFI Workplan and in Tables 3-8 through 3-10. The data are over 90 percent complete; i.e., 90 percent of the data meets statement of work specifications. With the current state of practice in this area, these data are of high quality and provide the detailed QC information needed to establish reproducibility and comparability. Target detection limits were met. Accuracy and precision values as defined in the QAPP have been summarized and included in the project files along with the data validation reports for data users.

## 3.3 References

Dames & Moore. *Phase II, Site Screening Investigation, Final Report*. Prepared for Rhône-Poulenc Inc., Seattle, Washington, October 1986.

Landau Associates, Inc. *Site Assessment, Rhône-Poulenc Facility, Tukwila, Washington*. Prepared for Boeing Environmental Affairs, Seattle, Washington, September 1991.

U.S. Environmental Protection Agency. *National Functional Guidelines for Organic Data Review*. June 1991.

U.S. Environmental Protection Agency. *Functional Guidelines for Evaluating Inorganic Analysis*. July 1988.

U.S. Environmental Protection Agency. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. Third Edition. Publication SW-846, 1992.

sea1002A251.wp5

4  
RFI FINDINGS AND  
ANALYTICAL RESULTS

## Section 4 RFI Findings and Analytical Results

This section presents the findings and results of the RFI at the Marginal Way Facility, with emphasis on the following:

- Hydrogeological conditions at the Facility
- The analytical results of the samples and data collected
- Comparison of the results to the action levels identified for the RFI
- The fate and transport of key constituents of concern in groundwater

As noted in previous sections, the RFI analytical results are compared to action levels in order to assess the need for further actions such as a Corrective Measures Study (CMS). Consistent with U.S. EPA guidance, action levels for this Facility have been based on health and environmental exposure levels and established cleanup standards. The action levels for soil are the state MTCA Method C cleanup levels. The action levels for groundwater are the federal Maximum Contaminant Levels (MCLs). For sediments, the action levels are the Minimum Cleanup Levels (MCULs) in the state Marine Sediment Management Standards.

The RFI findings and results are presented as follows in this section:

- 4.1, Hydrogeologic Characterization
- 4.2, Soil Investigation
- 4.3, Groundwater Investigation
- 4.4, Sediment Investigation
- 4.5, Ecological Site Assessment
- 4.6, Seep Assessment
- 4.7, Air Emissions Investigation
- 4.8, Fate and Transport of Constituents in Groundwater

The findings of the hydrogeological characterization are presented first. In this way, the subsequent discussions of the laboratory results for the various media can be presented within the framework of the subsurface conditions controlling the fate and transport of constituents. The description of the hydrogeological conditions is followed by sections presenting the findings and results of the various media investigations and the ecological site and seep assessments. The results indicate that groundwater is the medium of primary concern at the Facility, and Section 4 concludes with analyses of the potential fate and transport of key contaminants in groundwater and their propensity to reach the Duwamish Waterway and impact surface water quality.

## 4.1 Hydrogeologic Characterization

As noted in Section 2.2, the conceptual hydrogeologic model for the Facility was well developed prior to the RFI, and the RFI hydrogeologic characterization focused on confirming and augmenting existing Facility information. Additional hydrogeologic information was collected during the RFI through the soil and HydroPunch investigations, and during monitoring well installation.

### 4.1.1 Geology and Hydrostratigraphy

#### *Regional and Local Conditions*

The geomorphology and soil types of the Puget Sound Lowland were formed as deposits of glacial drift and interglacial sediments. Postglacial changes to this glacial drift plain included erosion and down-cutting from the White, Cedar, Green, and Duwamish Rivers. Alluvial or sedimentary deposits from this erosion subsequently filled the broad Duwamish River Valley embayment area. These sediments consist primarily of silt and sand.

Soils in the Duwamish River Valley were formed in these alluvial deposits and are part of the Oridia-Seattle-Woodinville soil association. These soils are composed of stratified silt loams, silty clay loams, and sandy loams, with layers of peat and muck that are characteristically level and somewhat- to very-poorly drained. Soil permeability is moderate to moderately low for the Oridia soils, moderate for the Seattle series soils, and moderately low for the Woodinville series soils.

Areas along the Duwamish Waterway have been built up and industrialized from the original tide-flat land surfaces. Such industrialized areas contain original soils modified by the addition of 3 to 12 feet of hydraulic fill materials. The fill materials present at the Facility consist of sediments dredged to straighten the meanders in the original Duwamish River and create the Duwamish Waterway.

#### *Facility-Specific Conditions*

In the immediate vicinity of the Facility, hydraulic fill consisting of dredged sand and silt is present in the upper 5 to 15 feet of the subsurface. The fill is underlain by alluvial silt and sand to depths of approximately 50 feet bgs. Because of the similarity between the hydraulic fill and the underlying native deposits, a contact point between the units can be difficult to determine visually. However, discontinuous layers or lenses of sand, silt, and clay present in the upper 15 feet of the subsurface appear to typify the hydraulic fill. Sand, silt, and clay deposits of marine origin underlie the above-referenced alluvial sediments.

The hydrostratigraphy of the (approximately) upper 100 feet at the Facility was first described by Dames & Moore (1986) as a five-layer system. The RFI data support this finding. The five-layer conceptual model includes two aquifers: an upper unconfined

aquifer and a lower confined aquifer. The five hydrostratigraphic units are described below (from top to bottom) and depicted in Figure 4-1.

- **Unsaturated Zone.** The Unsaturated Zone (or vadose zone) extends from the ground surface to a depth of 10 to 15 feet and is composed primarily of poorly graded silty sand and sandy silts. Depending on location, much of this material is hydraulic fill from historical dredging conducted to form and maintain the Duwamish Waterway. Localized areas of nonhydraulic construction fill may also be present onsite. Laterally discontinuous low-permeability silts and clays in the Unsaturated Zone cause perched groundwater conditions to form locally.
- **Upper Aquifer.** The Upper Aquifer consists of alluvial sands and silty sands deposited by the Duwamish River prior to dredging. The Upper Aquifer is generally unconfined but may be locally confined or semiconfined by the above-mentioned low-permeability silt and clay beds. Borings drilled before and during the RFI indicate that the Upper Aquifer is approximately 50 feet thick, extending from the groundwater table (approximately 10 to 15 feet bgs depending on location and tide stage) to a depth of 60 to 65 feet bgs.
- **Aquitard.** The Aquitard between the Upper and Lower Aquifers consists of silt and clay of alluvial origin. The Aquitard serves as a confining layer for the Lower Aquifer. Deeper borings drilled before and during the RFI indicate the Aquitard is laterally continuous and ranges in thickness from approximately 10 to 40 feet. The top of the Aquitard ranges in depth from 60 to 65 feet bgs; the bottom ranges in depth from 75 to 100 feet bgs. The average thickness is approximately 20 feet.
- **Lower Aquifer.** Consistent with the approved RFI Workplan, no borings were drilled during the RFI to investigate the Lower Aquifer. However, several borings have been drilled into the Lower Aquifer by Dames & Moore and Landau Associates. The logs for these borings indicate that the Lower Aquifer consists of marine sand and gravel. The potentiometric surface of this aquifer is 5 to 15 bgs. Boring B2, drilled by Dames & Moore near the shore of the Duwamish Waterway in 1979, suggests that the Lower Aquifer may be about 20 feet thick.
- **Lower Aquitard.** Glacial till is reportedly present beneath the Lower Aquifer (Dames & Moore, 1986). The till is underlain by siltstone. The till and siltstone are believed to have relatively low hydraulic conductivity and therefore likely represent an aquitard beneath the Lower Aquifer.

Figure 4-2 shows the locations of the 73 borings drilled during the RFI. These borings supplement existing geologic information provided by Dames & Moore (1979, 1986) and

Landau Associates (1991). The additional information allowed construction of hydro-stratigraphic cross-sections that are more detailed than those prepared previously by Dames & Moore or Landau. Four cross-sections were prepared; their locations are shown in Figure 4-3. The cross-sections are illustrated in Figures 4-4 through 4-7. The hydro-stratigraphic units are illustrated in the cross-sections and described below.

**Unsaturated Zone.** All of the 73 borings drilled during the RFI provided additional information on the Unsaturated Zone. Of particular interest were the presence and thickness of the silt and clay layer. Characterization of this layer was an RFI objective because the relatively low permeability of the material may influence the migration of liquid contaminants that infiltrate downward from the ground surface. A silt or clay layer capable of acting as a perching layer for groundwater was encountered in most borings drilled during the RFI. The stratigraphic cross-sections in Figures 4-4 through 4-7 show that the layer has an average thickness in the range of 5 to 8 feet. Figure 4-8 shows the approximate lateral extent of the layer. The presence of a buried root zone was typically observed at the top of the silt and clay. This root zone likely represents the ground surface prior to placement of hydraulic fill at the site.

The results of the physical property testing conducted on the Unsaturated Zone materials are shown in Table 4-1. The range of values for the Unsaturated Zone materials is shown in Table 4-2.

**Upper Aquifer.** The stratigraphy of the Upper Aquifer is characterized by fine to medium sand with lenses and beds of silty sand and sandy silt; the grain size distribution of the Upper Aquifer material generally becomes finer with depth. Drilling logs indicate that the average thickness of the Upper Aquifer is approximately 50 feet, extending from approximately 10 or 15 feet bgs to 60 or 65 feet bgs.

The results of the physical property testing conducted on the Upper Aquifer materials are shown in Table 4-1. The range of values for the Upper Aquifer materials is shown in Table 4-3.

**Aquitard.** As specified in the RFI Workplan, none of the RFI borings were drilled through the Aquitard separating the Upper and Lower Aquifers. However, borings A04-06, A04-14, A04-23, A04-24, and A02-05 were drilled into the Aquitard to confirm its presence and to collect samples for various physical tests. To date, 12 borings or wells have been drilled into or through the Aquitard by Dames & Moore (1979, 1986), Landau Associates (1991), and RPI (the above-referenced RFI borings).

The Aquitard is shown in the geologic cross-sections A-A' through D-D'. The boring log data indicate that the Aquitard is latterly continuous and ranges in thickness from 10 to nearly 50 feet; the average thickness is approximately 20 feet. Based on the geologic logs and grain size distribution data, the Aquitard materials consist of plastic silt and clay; however, layers of silty sand and abundant shell fragments have also been noted. As

shown in Tables 4-1 and 4-4, the laboratory hydraulic conductivity of the Aquitard materials ranges from  $7.7 \times 10^{-5}$  to  $2.5 \times 10^{-4}$  ft/day ( $2.7 \times 10^{-8}$  to  $8.8 \times 10^{-8}$  cm/sec).

The results of the physical property testing conducted on the Aquitard materials are shown in Table 4-1, and the range of values for these materials is shown in Table 4-4.

**Lower Aquifer and Lower Aquitard.** As discussed earlier, the Dames & Moore and Landau investigations characterized the Lower Aquifer materials as consisting of marine sand and gravel with an approximate thickness of 20 feet. The underlying Lower Aquitard reportedly consists of glacial till and siltstone.

#### 4.1.2 Groundwater Hydrology

The groundwater hydrology of the Facility is discussed below in two subsections. The first addresses hydraulic parameters for the Upper and Lower Aquifers, including hydraulic conductivity, transmissivity, and porosity; the hydraulic conductivity and porosity of the Aquitard materials are also discussed. The second subsection describes groundwater flow conditions at the Facility.

##### *Hydraulic Parameters*

**Hydraulic Conductivity of the Upper and Lower Aquifers.** As discussed in Section 2.2.3, single-well hydraulic conductivity tests ("slug" tests) were performed on six monitoring wells during the RFI. In addition, RPI conducted slug tests in 1991 on five other monitoring wells. For completeness, the 1991 data are presented here with the RFI data.

Of the 11 monitoring wells where slug tests have been conducted, eight are screened in the Upper Aquifer and three in the Lower Aquifer. These wells are grouped below by aquifer and year tested; their locations are shown in Figure 2-6.

##### Upper Aquifer Wells

B2 (1991)  
B6 (1991)  
H10 (1991)  
H11 (1991)  
DM-7 (1991)  
DM-1A (1994)  
DM-2A (1994)  
DM-3A (1994)

##### Lower Aquifer Wells

DM-1B (1994)  
DM-2B (1994)  
DM-3B (1994)

Slug test data were analyzed using the method described by Bouwer and Rice (1976) and Bouwer (1989). The rising-head data were used to calculate estimated hydraulic conductivity for the eight Upper Aquifer wells because all of these wells are screened across the

groundwater table. Both rising- and falling-head data were evaluated for the three monitoring wells screened in the Lower Aquifer. The hydraulic conductivity was calculated using the following equation:

$$K = \frac{r_c^2 \ln(R_e/r_w)}{2tL_e} \ln(y_o/y_t)$$

where:

K	=	hydraulic conductivity (ft/day)
R <sub>e</sub>	=	effective radius over which head is dissipated (ft)
r <sub>w</sub>	=	borehole radius (ft)
r <sub>c</sub>	=	well casing radius (ft)
L <sub>e</sub>	=	screen length (ft)
y <sub>o</sub>	=	head difference at time t <sub>o</sub> (ft)
y <sub>t</sub>	=	head difference at time t (ft)
t	=	time since t <sub>o</sub> (days)

Bouwer and Rice (1976) present an empirical formula to calculate R<sub>e</sub> based on the geometry of the well casing, borehole, and aquifer. Because the Upper Aquifer wells are screened across the groundwater table, drainage occurs in the filter pack around the well screen. To account for this, an equivalent well casing radius (equivalent r<sub>c</sub>) was calculated using the method described by Bouwer (1989, p. 305) and assuming a filter-pack porosity of 0.30.

The slug-test results are presented in Table 4-5. The calculated hydraulic conductivity values for the Upper Aquifer wells range from 0.5 to 100 ft/day; the geometric mean is 6.4 ft/day. The results are generally grouped at two ends of this range. Hydraulic conductivity values for wells H10, H11, and DM-7 range from 20 to 100 ft/day; these wells are located in the southwest part of the Facility near the former Tank Farm (see Figure 2-6). The remaining five wells are dispersed throughout the remainder of the Facility; hydraulic conductivity values at these wells range from 0.5 to 4.7 ft/day.

Calculated hydraulic conductivity values for the Lower Aquifer wells were relatively consistent, ranging from 0.2 to 0.6 ft/day; the geometric mean is 0.4 ft/day.

The estimated hydraulic conductivity values derived from the slug test data appear reasonably consistent with literature values for clean to silty fine sand. However, a formal aquifer test using pumping and observation wells would be necessary to design a groundwater extraction system, should such a corrective measure be deemed necessary.



**Transmissivity of Upper and Lower Aquifers.** Estimated transmissivities can be calculated for the Upper and Lower Aquifers using the equation:

$$T = Kb$$

where:

T	=	transmissivity (ft <sup>2</sup> /day)
K	=	hydraulic conductivity (ft/day)
b	=	aquifer thickness (ft)

As discussed above, mean (geometric) hydraulic conductivity values for the Upper and Lower Aquifers are 6.4 and 0.4 ft/day, respectively. Based on data collected during the RFI and previous investigations, the average thicknesses of the Upper and Lower Aquifers are approximately 50 and 20 ft, respectively. Using these data, estimated transmissivities are 300 and 8 ft<sup>2</sup>/day for the Upper and Lower Aquifers, respectively.

**Hydraulic Conductivity of the Aquitard.** The laboratory hydraulic conductivity values for four Aquitard samples are two to three orders of magnitude lower than the hydraulic conductivity results for the Upper and Lower Aquifers. The laboratory hydraulic conductivity values for the Aquitard materials range from  $7.7 \times 10^{-5}$  to  $2.5 \times 10^{-4}$  ft/day ( $2.7 \times 10^{-8}$  to  $8.8 \times 10^{-8}$  cm/sec); the geometric mean is  $1.6 \times 10^{-4}$  ft/day ( $5.7 \times 10^{-8}$  cm/sec). The laboratory hydraulic conductivity data for the Aquitard materials are presented in Table 4-1.

**Porosity.** Porosity was measured in the laboratory for selected soil samples collected from the Unsaturated Zone, the Upper Aquifer, and the Aquitard. The porosity of the Unsaturated Zone materials ranges from 37.1 to 46.3 percent, based on testing of five samples (Table 4-2). The porosity of the Upper Aquifer materials ranges from 33.2 to 40.7 percent, based on three samples (Table 4-3). The porosity of the Aquitard materials ranges from 32.2 to 54.5 percent, based on four samples (Table 4-4). The porosity values presented above are consistent with the grain size distribution in each of these hydrostratigraphic units.

### ***Groundwater Flow***

A groundwater elevation monitoring program was conducted to evaluate groundwater flow at the Facility. Data were collected to evaluate groundwater levels, horizontal groundwater flow and gradients, and the direction and magnitude of the vertical gradients between the Upper and Lower Aquifers. Of particular interest was the effect of tides in the Duwamish Waterway on the groundwater hydrology. Two types of groundwater-level measurements (electronic and manual) were used to collect data for this evaluation. Groundwater levels in ten monitoring wells and water levels in one surface water location (in the Duwamish Waterway) were monitored continuously from January 19 through February 15, 1994, using electronic datalogging equipment. Manual groundwater-level measurements were

collected four times at all 30 pre-RFI monitoring wells on February 4, 1994, to coincide with four specific tide stages (see Section 2.2.2).

The groundwater elevation data were used to evaluate horizontal and vertical hydraulic gradients and to prepare hydrographs and potentiometric contour maps. These data and associated findings are presented in this section.

It should be noted that the groundwater elevation data for well B1A have not been used in the preparation of potentiometric contour maps. A review of the well construction log for this well and groundwater elevation data for nearby wells indicates that well B1A is screened in a perched groundwater zone just above the Upper Aquifer. This conclusion is supported by groundwater elevation data showing that this well is not influenced by diurnal tides and, therefore, does not appear to be in direct hydraulic connection with the Upper Aquifer.

It should also be noted that a groundwater extraction program was being conducted in 1994 at the Kenworth Truck Company site located immediately north of the RPI Facility. Groundwater-level data collected during the RFI indicate that drawdown induced by the Kenworth extraction wells affected groundwater flow during the RFI in the western end of the RPI Facility. The Kenworth extraction program is addressed below so that the data presented later in this section are viewed in the appropriate context.

**Kenworth Groundwater Extraction System.** In May 1994 RPI was informed that the Kenworth Truck Company, as part of a voluntary cleanup action under MTCA, had been extracting groundwater at its site from January to May 1994—the same time that most of the RFI groundwater elevation data were collected. Based on information provided to RPI by Kenworth, groundwater had been pumped from three Upper Aquifer extraction wells at a total rate of approximately 60 gallons per minute. The extraction wells are located in the north-central portion of the Kenworth property, approximately 700 feet north of RPI monitoring wells B1A and B1B (Figure 4-3 shows the locations of these wells).

In an attempt to evaluate the potential effects of Kenworth's extraction system on the groundwater flow patterns at the RPI facility, an additional round of groundwater-level measurements was conducted in June 1994. This round was timed to coincide with a period when Kenworth's system was not in operation.

Potentiometric contour maps for the Upper Aquifer were prepared from RFI groundwater elevation data obtained during periods when Kenworth's extraction system was in operation. These maps were compared to the Upper Aquifer map prepared from the June 1994 round of groundwater-level measurements (which were taken when Kenworth had ceased extraction operations temporarily). A comparison of these maps indicates that drawdown from the Kenworth wells affected groundwater flow in the northwest portion of the RPI Facility. This is further supported by theoretical drawdown calculations (using Facility-specific aquifer parameter data and Kenworth pumping information) indicating that

Kenworth pumping could cause Upper Aquifer groundwater levels in the western portion of the RPI Facility to decline as much as 1 to 2 feet.

In the absence of Kenworth pumping, it is believed that the net groundwater flow direction in the Upper Aquifer is likely toward the west, with ultimate discharge to the Duwamish Waterway (or to Slip No. 6). During Kenworth pumping, however, the net groundwater flow direction in part of the Facility appears to be northward, toward the Kenworth property. This is consistent with the location of the Kenworth extraction wells. The potentiometric contour maps and associated discussions are presented later in this section.

**Groundwater Elevation Hydrographs.** Groundwater elevation hydrographs for each of the electronically monitored wells (see Table 4-6) are presented in Figures 4-9 through 4-14.

- **Wells DM-1A and DM-1B.** Figure 4-9 shows hydrographs of groundwater elevations in wells DM-1A and DM-1B from January 19 through February 15, 1994. The diurnal tidal cycle is evident in both wells, although the response to tidal fluctuations is slightly less pronounced in the Upper Aquifer well DM-1A. The effects of the diurnal tide cycles are less pronounced in this well pair relative to the other wells monitored because these wells are located farther from the Duwamish Waterway and Slip No. 6.

In addition to tidal trends, it is important to note that an upward vertical gradient exists between the Lower Aquifer (DM-1B) and the Upper Aquifer (DM-1A) at all times during the 27-day monitoring period. The net upward vertical gradient from DM-1B to DM-1A has been calculated as 0.05 (feet vertical/feet horizontal) based on the average of the groundwater-level measurements collected over the 27-day period.

- **Wells DM-2A and DM-2B.** Figure 4-10 shows hydrographs of wells DM-2A and DM-2B from January 19 through February 15, 1994. The diurnal tidal cycle in both wells is very pronounced owing to their location near the Duwamish Waterway and Slip No. 6. Daily groundwater-level variations are greater in the Lower Aquifer (DM-2B) than in the Upper Aquifer (DM-2A), and there is a lag in response time to tidal changes in the Upper Aquifer relative to the Lower Aquifer.

An upward vertical gradient from DM-2B to DM-2A is apparent from the data. At no time does the DM-2B hydrograph cross below the DM-2A hydrograph, indicating that the gradient is always upward regardless of the tide stage. The net upward vertical gradient from DM-2B to DM-2A has been calculated as 0.05 ft/ft based on the average of the groundwater-level measurements collected over the 27-day period.

The sudden drop in the recorded water level in DM-2B on January 21, 1994, was the result of the transducer being removed from the well so that groundwater sampling could be performed. The anomalous portion of the hydrograph is labeled "groundwater sampling."

- **Wells DM-3A and DM-3B.** Figure 4-11 shows hydrographs of wells DM-3A and DM-3B from January 19 through February 15, 1994. The diurnal tidal cycle is evident in both wells. However, groundwater-level variations are greater in DM-3B (Lower Aquifer) than in DM-3A (Upper Aquifer).

An upward vertical gradient from DM-3B to DM-3A is apparent from the hydrographs. At no time does the DM-3B hydrograph cross below the DM-3A hydrograph. This indicates that the vertical gradient is always upward at this location, regardless of the tide stage. The net upward vertical gradient from DM-3B to DM-3A is calculated as 0.07 ft/ft based on the average of the groundwater-level measurements collected over the 27-day period.

Groundwater sampling was performed at wells DM-3A and DM-3B on January 20, 1994. The drop in the groundwater level shown in the hydrographs for these wells was caused by removal of the transducer prior to sampling. The anomalous portions of the hydrographs are labeled "groundwater sampling."

- **Wells H1 and H10.** Figure 4-12 shows hydrographs of wells H1 and H10 from January 19 through February 15, 1994. Both wells are screened in the Upper Aquifer. Well H10 is screened across the groundwater table; well H1 is screened near the bottom of the aquifer. Groundwater elevations in both wells are similar, with no observable time lag in tidal response between the two wells. A very slight net downward gradient of 0.001 ft/ft is calculated for the Upper Aquifer based on average groundwater elevations for the period from January 13 through February 3, 1994.
- **Wells B1A and B1B.** Figure 4-13 shows hydrographs of well B1A (intended as an Upper Aquifer well) and B1B (a Lower Aquifer well) from January 19 through February 15, 1994. Diurnal tidal cycles are not apparent in the hydrograph for B1A but are present in the hydrograph for B1B. Based on (1) the relatively high groundwater elevation compared to nearby wells, (2) the boring log, and (3) the lack of diurnal tidal response, well B1A appears to be screened in a perched water-bearing zone rather than in the Upper Aquifer. Therefore, calculation of a vertical hydraulic gradient between wells B1A and B1B would not be meaningful.

Monitoring well B1B was sampled on January 19, 1994. The resulting drop in the groundwater level can be seen in the hydrograph and is labeled "groundwater sampling."

- **Stilling Well Water-Level Elevations.** Figure 4-14 shows a hydrograph of water-level elevations measured in the stilling well installed in the Duwamish Waterway. This hydrograph indicates the magnitude and timing of tidal fluctuations during the monitoring period. Water levels in the Duwamish Waterway varied by as much as 12 to 13 feet between high and low tides. Ten minus tides occurred during the 27-day monitoring program (the lowest tide was minus-1.2 feet [mean lower low water] on January 26 and 27, 1994).

**Potentiometric Contour Maps.** Potentiometric contour maps were developed for the Upper and Lower Aquifers beneath the Facility, as described below:

- **Discrete tidal stages.** Four rounds of groundwater elevation data were collected on February 4, 1994, using electronic water-level indicators. The four rounds corresponded to mid-tide rising, high tide, mid-tide falling, and low tide. Discrete tide-stage potentiometric maps for the Upper and Lower Aquifers were developed from these data. These data were collected at a time when groundwater extraction was occurring at the Kenworth site located immediately north of the RPI Facility.

An additional round of groundwater elevation data was collected manually on June 23, 1994, during a high-tide event. These data were collected at a time when Kenworth was not pumping in order to evaluate Upper Aquifer groundwater flow under pumping and non-pumping conditions.

- **27-day averages.** Groundwater elevation data collected at 15-minute intervals by an electronic datalogger were averaged for the period January 19 through February 15, 1994. These data were used to create 27-day average potentiometric contour maps for the Upper and Lower Aquifers. The wells monitored during this period are shown in Table 4-7 along with the average groundwater elevations used to develop the contour maps. These data were collected during Kenworth pumping conditions.

**Upper Aquifer Potentiometric Groundwater Contour Maps.** Each Upper Aquifer groundwater contour map (Figures 4-15 through 4-20) is discussed below. The discussions focus on groundwater flow directions and horizontal hydraulic gradients in the Upper Aquifer.

- **Figure 4-15: Upper Aquifer, Mid-Tide Rising, 2/4/94 at Approximately 0715.** The groundwater elevation contours shown in Figure 4-15 indicate that groundwater flow is from east to west in the eastern two-thirds of the Facility. Upper Aquifer groundwater beneath the Background Area (the vicinity of wells DM-1A and E3) appears to be flowing toward the process area and toward Slip No. 6. In the western third of the Facility, groundwater flow converges from the east, west, and south forming a north-south-oriented potentiometric trough underlying the Distribution Center. Groundwater below, and north of, the Distribution Center appears to be flowing northward toward the Kenworth site;

this is believed to be a consequence of Kenworth's groundwater extraction system.

Hydraulic gradients are relatively flat in the Background Area and the central portion of the Facility. The gradients are steeper along the Duwamish Waterway and Slip No. 6 shorelines where the Upper Aquifer is recharged by these surface water bodies.

- Figure 4-16: Upper Aquifer, High Tide, 2/4/94 at Approximately 1015.** Figure 4-16 indicates that at high tide, Upper Aquifer groundwater flow conditions are similar to the mid-tide rising stage (Figure 4-15). The potentiometric trough located in the vicinity of the Distribution Center is still present, consistent with the potentiometric depression depicted in the equivalent (high-tide) potentiometric contour map presented by Landau Associates (1991). The Landau contour map depicts groundwater flow converging on the western third of the Facility, resulting in the presence of a potentiometric depression. The inward hydraulic gradient along the shorelines of the Duwamish Waterway and Slip No. 6 is steeper because of the high tide. Based on the conditions shown in Figure 4-16, it appears that the groundwater extraction system at the Kenworth site affects groundwater flow at the RPI Facility.

The Upper Aquifer groundwater flow direction in most of the Background Area is east to west. However, flow at the east end of Slip No. 6 is reversed relative to Figure 4-15 (mid-tide rising); groundwater is flowing from Slip No. 6 to the east. Of the four tide stages contoured, high tide is the only tide stage where the groundwater flow direction at the east end of Slip No. 6 is from west to east. This flow reversal is believed to occur only over a short distance from the shoreline. During the other three tide stages monitored, Upper Aquifer groundwater from the eastern end of the Facility discharges to Slip No. 6.

- Figure 4-17: Upper Aquifer, Mid-Tide Falling, 2/4/94 at Approximately 1415.** The Upper Aquifer groundwater elevation contours shown in Figure 4-17 for the mid-tide falling stage indicate that the north-south oriented potentiometric trough remains present in the western third of the Facility; again, this is believed to be a consequence of Kenworth's groundwater extraction system. Flow remains inward from Duwamish Waterway and Slip No. 6 in the western half of the Facility; however, gradients along the shorelines are flatter compared to high-tide conditions. Recharge to the Upper Aquifer in the Background Area of the Facility is from the east-northeast, with discharge to Slip No. 6. Groundwater flow converges on the west-central portion of the Facility from the east and from Slip No. 6 and the Duwamish Waterway. Discharge from the west-central portion of the Facility is toward the north property line during this tide stage.

Hydraulic gradients in the background area, the central portion of the Facility, and along the shoreline are relatively flat. Away from the shoreline areas, the steepest hydraulic gradients are in the central portion of the Facility.

- **Figure 4-18: Upper Aquifer, Low Tide, 2/4/94 at Approximately 1745.** The groundwater elevation contours shown in Figure 4-18 indicate that Upper Aquifer groundwater flow directions are generally westerly and southwesterly toward the Duwamish Waterway and Slip No. 6 during low tide. The potentiometric trough shown in the previous figures is no longer present. The hydraulic effect of the low-tide condition causes groundwater levels near the shoreline to decline to the extent that drawdown induced by Kenworth pumping is not evident. Recharge to the Upper Aquifer appears to be from the east or the northeast with discharge to the Duwamish Waterway and Slip No. 6. The potentiometric contours shown in Figure 4-18 are consistent with the contour map presented by Landau Associates (1991) for the Upper Aquifer at low tide.

Surface water elevations were significantly lower than groundwater levels measured in Upper Aquifer monitoring wells along the shoreline, indicating a steep hydraulic gradient along the shorelines of the Duwamish Waterway and Slip No. 6.

- **Figure 4-19: Upper Aquifer, High Tide, 6/23/94 at Approximately 1900.** Groundwater elevations were measured at high tide on June 23, 1994, approximately one month after groundwater extraction had stopped at Kenworth. As discussed previously, the June high-tide measurements were conducted to allow comparison with groundwater elevations and flow conditions as measured during high tide on February 4, 1994, when the Kenworth extraction system was operating (Figure 4-16).

A comparison of Figure 4-19 with Figure 4-16 shows that a groundwater depression existed in the western third of the site on June 23. Flow toward the Kenworth site is not evident. Groundwater flow conditions in other parts of the site (the Background Area, the east end of Slip No. 6, and the shoreline areas) appear similar for the June 23 and February 4 monitoring events. The inferred groundwater flow toward the Kenworth site on February 4, and the absence of such flow on June 23, supports the previously stated belief that the Kenworth extraction system was influencing groundwater levels and flow conditions at the RPI Facility. Further, groundwater flow depicted for high tide on June 23 is consistent with the equivalent (high-tide) contour map presented by Landau Associates (1991). The Landau potentiometric contour map for the Upper Aquifer at high tide also depicts groundwater converging on the western third of the Facility and the presence of a potentiometric depression.

- **Figure 4-20: Groundwater Contours, Upper Aquifer, 27-Day Average, 1/19/94 through 2/15/94.** Figure 4-20 shows Upper Aquifer groundwater

elevation contours representing the average groundwater levels for the 27-day monitoring period. The contours indicate that net groundwater flow in the eastern two-thirds of the Facility is east to west, consistent with the expectation that local groundwater is moving toward the Duwamish Waterway. However, a potentiometric trough is evident in the western third of the Facility. The trough is formed by groundwater converging from the east, west (from the Duwamish Waterway), and south (from Slip No. 6). Again, the contours in this area are consistent with conditions that would occur if the net groundwater flow direction is northward toward the Kenworth site. This is contrary to the westerly flow (toward the Duwamish Waterway) that would be expected under normal conditions (i.e., in the absence of Kenworth pumping). The groundwater extraction occurring at the Kenworth site during the 27-day period of continuous monitoring is believed to be the cause of the apparent northerly flow. This is supported by hydraulic calculations indicating that 1 to 2 feet of drawdown could be induced in the west-central portion of the Facility by groundwater extraction at the Kenworth site at a cumulative rate of 60 gallons per minute (gpm).

The net horizontal hydraulic gradient shown in Figure 4-20 for the eastern two-thirds of the Facility is consistent with the expectation that groundwater is moving east toward the Duwamish Waterway. The horizontal hydraulic gradient across the eastern two-thirds of the Facility is relatively uniform at approximately 0.002 ft/ft. In the western third of the Facility, groundwater appears to converge from the east, south, and west and to flow northward under a relatively low hydraulic gradient. However, current groundwater elevation data for this area of the Facility are not adequate to establish a definitive groundwater flow direction or an estimated gradient.

*Lower Aquifer Potentiometric Groundwater Contour Maps.* An evaluation of each Lower Aquifer groundwater contour map (Figures 4-21 through 4-26) is presented below. The evaluations focus on inferred groundwater flow directions and hydraulic gradients in the Lower Aquifer. There are only four monitoring wells screened in the Lower Aquifer. Therefore, the groundwater flow directions inferred from the groundwater elevation data must be considered more approximate than those depicted for the Upper Aquifer.

- **Figure 4-21: Lower Aquifer, Mid-Tide Rising, 2/4/94 at Approximately 0715.** The groundwater elevation contours shown in Figure 4-21 indicate that at the time of measurement (mid-tide rising), groundwater in the Lower Aquifer was flowing from the southeast to the northwest across the Facility. During this tide stage, recharge to the Lower Aquifer appears to be from the southeast with discharge to the northwest.

The hydraulic gradient is approximately 0.002 ft/ft across the Facility during this tide stage.



- **Figure 4-22: Lower Aquifer, High Tide, 2/4/94 at Approximately 1015.** The groundwater elevation contours shown in Figure 4-22 indicate that flow was toward the northeast in the western portion of the Facility and toward the northwest in the eastern and southeastern portions of the Facility. High tide is the only tide stage monitored when Lower Aquifer groundwater is not moving from east to west. The contours shown in Figure 4-22 are consistent with those shown by Landau Associates (1991) for the Lower Aquifer at high tide.

The hydraulic gradient shown in Figure 4-22 is approximately 0.002 ft/ft, consistent with the gradient depicted by Landau Associates for the Lower Aquifer at high tide.

- **Figure 4-23: Lower Aquifer, Mid-Tide Falling, 2/4/94 at Approximately 1415.** The groundwater elevation contours of the Lower Aquifer shown in Figure 4-23 indicate flow from east to west toward the Duwamish Waterway. The hydraulic gradient across the Facility is approximately 0.002 ft/ft.
- **Figure 4-24: Lower Aquifer, Low Tide, 2/4/94 at Approximately 1745.** The groundwater elevation contours shown in Figure 4-24 indicate flow from east to west toward the Duwamish Waterway, in the same direction shown for the mid-tide falling stage (Figure 4-23). The contours shown in Figure 4-24 are consistent with those shown by Landau Associates (1991) for the Lower Aquifer at low tide.

The hydraulic gradient shown in Figure 4-24 is steeper (approximately 0.003 ft/ft) than those depicted in the other contour maps for the Lower Aquifer, and is consistent with the gradient depicted by Landau Associates for the Lower Aquifer at low tide.

- **Figure 4-25: Lower Aquifer, High Tide, 6/23/94 at Approximately 1900.** As discussed previously, groundwater elevations were measured at high tide on June 23, 1994, to evaluate the potential hydraulic effect that the Kenworth groundwater extraction system may have had on the groundwater levels measured on February 4, 1994. Comparison of Figure 4-25 with Figure 4-22 shows that there is little difference in the groundwater flow conditions in the Lower Aquifer at high tide. Like the conditions shown for February 4, Lower Aquifer groundwater flow at high tide is toward the northwest in the eastern and southeastern portions of the Facility. The potentiometric contours for the Lower Aquifer at high tide, shown in Figures 4-22 and 4-25 and by Landau Associates, are all consistent in this regard.
- **Figure 4-26: Groundwater Contours, Lower Aquifer, 27-Day Average 1/19/94 through 2/15/94.** The net potentiometric contours for the Lower Aquifer indicate that groundwater flow is generally from east to west toward the Duwamish Waterway. As groundwater enters the western third of the Facility

and approaches the Duwamish Waterway, the flow direction changes from westerly to southwesterly. This change in flow direction may be due to the hydraulic influence of Slip No. 6. The hydraulic gradient in the Lower Aquifer is approximately 0.002 ft/ft across most of the Facility.

**Vertical Groundwater Flow Potential and Gradients.** Net vertical gradients between the Upper and Lower Aquifers were calculated based on the average of long-term (27-day) groundwater elevation data collected at three well pairs: DM-1A/DM-1B, DM-2A/DM-2B, and DM-3A/DM-3B (wells with the "A" suffix are screened in the Upper Aquifer; wells with the "B" suffix are screened in the Lower Aquifer). The direction of the net vertical gradient is significant because it indicates the direction of the hydraulic head potential and, therefore, the direction of potential groundwater flow across the Aquitard separating the Upper and Lower Aquifers. A downward flow potential would promote the vertical migration of groundwater constituents from the Upper to the Lower Aquifer. Conversely, an upward gradient would inhibit the downward migration of constituents.

The direction of the calculated net vertical gradient at each well is upward from the Lower to the Upper Aquifer. The calculated net vertical gradients are shown in Table 4-8. The directions of the head potential shown in the table are in the upward in all cases, consistent with the hydrographs for well pairs DM-1A/DM-1B, DM-2A/DM-2B, and DM-3A/DM-3B (Figures 4-9, 4-10, and 4-11). Based on the 27-day groundwater elevation monitoring program, these hydrographs indicate that the direction of the vertical gradient between the Lower and the Upper Aquifer is upward at all times and during all tide stages (i.e., the groundwater elevation for a Lower Aquifer well is always higher than the groundwater elevation in the adjacent Upper Aquifer well).

Table 4-9 summarizes the net groundwater-level differences at each of the well pairs monitored during discrete tide stages on February 4, 1994. The 27-day average groundwater level is also shown.

Figures 4-27 through 4-30 show vertical potentiometric contour lines plotted on four hydro-stratigraphic cross-sections. The cross-section locations correspond to the locations of cross-sections presented earlier (in Figures 4-4 through 4-7). The groundwater elevations and potentiometric contours shown in the figures represent the average of groundwater-level measurements made during four tide stages on February 4, 1994 (see Section 2.2.2). In all four cross-sections, the upward gradient across the Aquitard separating the Upper and Lower Aquifers is depicted and supported by the groundwater elevations shown.

**Tidal Efficiency and Time Lag.** Tidal efficiency and time lag were calculated for eight monitoring wells included in the 27-day groundwater elevation monitoring program: wells DM-1A/DM-1B, DM-2A/DM-2B, DM-3A/DM-3B, B1B, and H10. Tidal efficiency and time lag were not calculated for two of the 10 wells monitored (B1A and H1) for the following reasons:

- Well B1A is screened in perched groundwater and is not tidally influenced.
- Well H1 is located immediately adjacent to well H10 and is similarly screened in the Upper Aquifer; a comparison of the hydrographs for these two wells (Figure 4-12) shows that they respond almost identically to tidal influences. Therefore, calculation of tidal efficiency and time lag for both wells would be redundant.

The stilling well installed in the Duwamish Waterway was used as the indicator of tidal fluctuations. Calculations of tidal efficiency and time lag were based on data collected on February 9 and 10, 1994. In order to negate the effects of barometrically induced water-level changes, the data used for the tidal efficiency calculations were corrected for barometric effects. Table 4-10 presents a summary of the calculated tidal efficiency and time lag results for the eight monitoring wells.

As expected, the tidal efficiency of wells screened in the same aquifer decreases with increasing distance from the Duwamish Waterway (or from Slip No. 6). Where there are paired wells screened in both the Upper and Lower Aquifers, the well efficiency for the Lower Aquifer well is always greater than for the Upper Aquifer well. This is consistent with the Facility hydrostratigraphic data indicating that the Lower Aquifer is confined. Well efficiencies are highest in the Lower Aquifer wells adjacent to the Duwamish Waterway (45 percent at DM-2B and 40 percent at DM-3B) and lowest (1 percent) in Upper Aquifer well DM-1A located at the east end of the Facility and distant from the Waterway.

Also as expected, the tidal lag time for wells screened in the same aquifer increases with distance from the Duwamish Waterway. Where there are paired wells screened in both the Upper and Lower Aquifers, the time lag for the Lower Aquifer well is significantly less than that observed for the Upper Aquifer well. The tidal time lag for the Lower Aquifer wells along the Duwamish Waterway (wells DM-2B and DM-3B) is nil, consistent with the hydrostratigraphic data indicating that the Lower Aquifer is confined.

**Summary of Groundwater Flow Conditions.** Groundwater levels in the Upper and Lower Aquifers oscillate constantly in response to tidal fluctuations in the Duwamish Waterway and Slip No. 6. The tidally induced groundwater-level fluctuations cause horizontal groundwater flow directions and gradients to change constantly. A 27-day groundwater elevation monitoring program was conducted at selected wells to establish the net groundwater flow direction and gradient in each aquifer. The results indicate that the net horizontal groundwater flow direction in the Lower Aquifer is from east to west under a hydraulic gradient of approximately 0.002 ft/ft (see Figure 4-26).

Under natural conditions, it is believed that horizontal flow in the Upper Aquifer is also from east to west under a hydraulic gradient of approximately 0.002 ft/ft, with Upper Aquifer groundwater ultimately discharging to the Duwamish Waterway or to Slip No. 6. The RFI groundwater elevation data support this assumption for the eastern two-thirds of the Facility, where groundwater flows in a westerly direction. However, a north-south-

oriented potentiometric trough is evident in the western third of the Facility (see Figure 4-20). The data suggest that horizontal groundwater in this western portion of the Facility converges from the west, south, and east and flows in a northerly direction. This northerly groundwater flow is believed to be caused by the hydraulic influence of the groundwater extraction system that was in operation at the Kenworth site at the time the groundwater elevation data were collected.

The RFI groundwater elevation data indicate that the vertical hydraulic head potential between the Upper and Lower Aquifers is in the upward direction at all times, regardless of tide stage. The net vertical gradient across the Aquitard separating the Upper and Lower Aquifers ranges from 0.05 to 0.07 ft/ft, depending on location.

## 4.2 Soil Investigation

As discussed in Sections 2.1 and 2.3, soil samples were collected within each of the 10 soil investigation areas and the Background Area during the RFI. The analytical parameters for the soil samples were specific to each investigation area and included the previously identified preliminary constituents of concern. They were selected based on past Facility practices and the frequency with which they were detected in previous investigations. The parameters selected for each area include a subset of the following: inorganic constituents ("inorganics"), volatile organic compounds ("volatiles"), semivolatile organic compounds ("semivolatiles"), pesticides/PCBs, isopropyl alcohol, total petroleum hydrocarbons (TPH), and formaldehyde.

The results of the Round 1 soil sampling effort are summarized in Figures 4-31 through 4-41. Each figure contains an investigation area map showing the sample locations and a table summarizing the analytical results. The table presents each detected parameter by chemical group and lists several statistics for that parameter, including the maximum and minimum value detected, the frequency of the detections, and the mean. (Nondetected values were included to calculate the mean and were assigned a value of one-half the method detection limit for this purpose.) The table in each figure also presents the action level for each constituent detected. As discussed earlier in this report, the action levels for soil are the MTCA Method C cleanup levels. The results for specific samples and parameters are listed in the RFI database presented in Appendix D. (Note: Appendix D lists detected constituents only; nondetected constituents are not listed.)

The Round 2 soil data are summarized in Table 4-11. The results of the physical property tests conducted for soil are provided in Table 4-1 and Appendix H.

A photoionization detector (PID) was used to screen all samples for the presence of volatiles. A discrete sample (separate from that sent to the laboratory) was used for the PID monitoring; the results were recorded in the field logbooks with their corresponding depths.

The laboratory results for toluene were compared to PID field screening data, which are summarized in the plot shown in Figure 4-42. The comparison was conducted to determine if a correlation exists between PID readings and toluene data that would be helpful in further assessing the extent of toluene contamination. The relationship between the PID headspace measurements and laboratory analyses for toluene is relatively poor: a regression analysis of the PID headspace data and laboratory results for toluene yields an R-squared value of 0.27. (The R-squared value is an indicator of the reliability of the regression. The possible values range from 0 [no relationship between the two sets of variables] to 1 [a perfect relationship]). Therefore, PID readings alone are not believed to be a reliable indicator for the presence of toluene in soil.

As described in the RFI Workplan and Section 2.3 of this report, the initial soil sampling strategy called for only surface soil to be sampled in Areas A1, A3, A6, A8, A9, and A10. Areas A2, A4, A5, A7, and BG were to have both surface and subsurface samples collected during the RFI. The results of the surface sampling in Areas A1, A3, A6, A8, A9, and A10 are presented in Section 4.2.1. The results of the surface and subsurface sampling in the other areas are presented in Section 4.2.2. A complete listing of all constituents detected in each investigation area is presented in Figures 4-31 through 4-41. The discussions in Sections 4.2.1 and 4.2.2 do not address every constituent detected in each area, but focus on those constituents that:

- were previously identified as preliminary constituents of concern for soil (see Table 2-1);
- were found to exceed their respective action level at least once; or
- are otherwise noteworthy because of their toxicity, high frequency of detection, historical use at the Facility, or high concentration relative to conditions in Area BG (the Background Area).

The area-specific discussions address selected volatiles and semivolatiles (depending on concentration, frequency of detection, and toxicity), PCBs, TPH, formaldehyde, and isopropyl alcohol (2-propanol). Many of the inorganic constituents detected occur naturally in soil (e.g., aluminum, iron, magnesium, and calcium, among others); detection of these constituents was expected and does not typically indicate an anthropogenic source of contamination unless the concentrations are unusually high. As such, only three inorganic constituents are specifically addressed in Sections 4.1.2 and 4.2.2:

- **Arsenic.** Arsenic is addressed because it has been identified as a preliminary constituent of concern for soil (Table 2-1) and was detected once during the RFI at a concentration exceeding its action level of 57.1 mg/kg.
- **Copper.** Copper is addressed because it was detected in certain investigation areas at concentrations up to one to two orders of magnitude above the average concentration for investigation area BG.

- **Mercury.** Mercury is addressed because it was detected once during the RFI at a concentration above its action level of 96 mg/kg.

#### 4.2.1 Surface Soil Samples

Seven surface soil samples were collected and analyzed in Round 1 from each of the investigation areas A1, A3, A6, A8, A9, and A10. Surface soil is defined as the first soil encountered following the removal of asphalt or concrete paving, debris, or grass at each location (see Section 2.3.1). Samples from a depth interval of 0 to 2 feet below ground surface (bgs) were collected from Area A6 during Round 2. The detected constituents of concern within each investigation area and comparisons with their respective action levels are presented in the following subsections.

##### *Area A1*

The seven soil samples collected in Area A1, the Boneyard/Distribution Center, were analyzed for inorganics, volatiles, semivolatiles, and formaldehyde. The sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-31 and Appendix D.

Following is a summary of the soil results for Area A1:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 2.1 to 7.6 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in six samples at concentrations ranging from 15.1 to 6,850 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in three samples at concentrations ranging from 0.29 to 0.45 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Three volatiles were detected as follows:
  - 2-Butanone—detected in one sample at 0.002 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in two samples at 0.003 and 0.004 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in one sample at 0.022 mg/kg, below the action level of 64,000 mg/kg.

- **Semivolatiles.** Two semivolatiles were detected as follows:
  - Pentachlorophenol—detected in four samples at concentrations ranging from 0.083 to 4.9 mg/kg, below the action level of 333 mg/kg.
  - Vanillin—detected in three of six samples analyzed at concentrations ranging from 0.063 to 450 mg/kg. There is no MTCA Method C cleanup level for vanillin. (Note: The RFI Workplan did not call for vanillin analyses of Area A1 soil samples, but the analyses were conducted by the laboratory and the results are presented here for completeness.)
- **Formaldehyde.** Formaldehyde was detected in six samples; concentrations ranged from 0.058 to 0.47 mg/kg, below the action level of 64,000 mg/kg.

**Area A1 Summary:** While metals, volatiles, and semivolatiles were detected, none of the concentrations exceeded its respective action level (the MTCA Method C cleanup level). No additional samples were collected from Area A1 during Round 2.

### **Area A3**

The seven soil samples collected in Area A3, the Laboratory and Compressor Area, were analyzed for inorganics, volatiles, PCBs, and TPH. Four additional surface samples (from 0 to 0.5 foot bgs) were collected in the former compressor area and analyzed for PCBs and multichlorinated benzenes. The sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-33 and Appendix D.

Following is a summary of the soil results for Area A3:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 2.4 to 5.2 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in three samples at concentrations ranging from 59.6 to 485 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in two samples at concentrations of 0.15 mg/kg and 0.32 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Three volatiles were detected as follows:
  - Methylene chloride—detected in two samples; concentrations ranged from 0.002 to 0.004, below the action level of 5,330 mg/kg.

- Acetone—detected in two samples at 0.004 mg/kg each, below the action level of 32,000 mg/kg.
- Toluene—detected in four samples; concentrations ranged from 0.003 to 0.019, below the action level of 64,000 mg/kg.
- **PCBs.** Aroclor-1254 was detected in all of the four samples collected; concentrations ranged from 0.23 to 2.8 mg/kg, below the action level of 5.19 mg/kg.
- **TPH.** TPH was detected in three of the seven samples analyzed; concentrations ranged from 88.8 to 635 mg/kg. While there is no MTCA Method C cleanup level for TPH, the MTCA Method A cleanup level is 200 mg/kg. The TPH concentration in one sample exceeded this criterion (A03-02-01 at 635 mg/kg).

**Area A3 Summary:** While PCBs, metals, and volatiles were detected, none of the concentrations exceeded its respective action level (the MTCA Method C cleanup level). The TPH concentration in one sample exceeded the MTCA Method A cleanup level of 200 mg/kg; TPH in soil is discussed further in Section 4.2.3.

### **Area A6**

The seven soil samples collected during Round 1 in Area A6, the Maintenance Shop Area, were analyzed for inorganics, volatiles, TPH, and formaldehyde. The sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-36 and Appendix D.

Following is a summary of the Round 1 soil results for Area A6:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 1.1 to 6.7 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in five of the samples at concentrations ranging from 57.9 to 712 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in five samples at concentrations ranging from 0.62 to 268 mg/kg. The mercury concentration in sample A06-03-01 was 268 mg/kg, higher than the action level of 96 mg/kg. The concentrations detected in the remaining four samples were below the action level.
- **Volatiles.** Two volatiles were detected as follows:



- Acetone—detected in one sample at 0.003 mg/kg, below the action level of 32,000 mg/kg.
- Toluene—detected in five samples at concentrations ranging from 0.002 to 0.025, below the action level of 64,000 mg/kg.
- **Formaldehyde.** Formaldehyde was detected in six samples at concentrations ranging from 0.19 to 0.94 mg/kg, below the action level of 64,000 mg/kg.
- **TPH.** TPH was detected in three samples; concentrations ranged from 92.7 to 645 mg/kg. While there is no MTCA Method C cleanup level for TPH, the MTCA Method A cleanup level is 200 mg/kg. TPH concentrations in two samples exceeded this criterion (A06-01-01 at 645 mg/kg and A06-05-01 at 227 mg/kg).

Only one sample from investigation area A6 exceeded its respective action level—sample A06-03-01, with a mercury concentration of 268 mg/kg (the MTCA Method C level is 96 mg/kg). None of the other six samples analyzed exceeded the action level or even the more restrictive MTCA Method B cleanup level of 24 mg/kg. Because of the one exceedance of the action level, mercury was targeted for additional sampling in Round 2. Unlike arsenic and PAHs, which are known to be present regionally at relatively high concentrations, high mercury concentrations were unexpected and were believed to warrant further investigation. Based on historical information, the only potential source of the mercury detected would have been the former Maintenance Shop, where mercury-containing instruments were likely used. A release from a broken instrument is a possible explanation for the one elevated mercury concentration.

Additional soil sampling was undertaken during Round 2, on August 10, 1994, to confirm the presence of mercury in the vicinity of sample location A06-03 and to determine its possible distribution in Area A6. Sixty-eight samples were collected from 34 locations. These consisted of 34 surface samples (from 0 to 0.5 foot bgs) and 34 subsurface samples (from 1.5 to 2.0 feet bgs). Of these, 38 samples (34 surface and 4 subsurface) were analyzed for mercury. None of these additional samples indicated mercury concentrations above the action level. The remaining 30 subsurface samples were not analyzed because the surface samples collected at the same locations did not indicate mercury above either action levels or MTCA Method B (24 mg/kg) cleanup levels. The analytical results are presented in Table 4-12 and Figure 4-43.

**Area A6 Summary:** While metals, volatiles, and semivolatiles were detected in the Round 1 soil investigation, only one sample exceeded its respective action level—sample A06-03-01, with a mercury concentration of 268 mg/kg exceeding the MTCA Method C cleanup level of 96 mg/kg. Mercury was targeted for additional sampling that was conducted during Round 2, but the analytical results did not indicate mercury above either its action level or the more restrictive MTCA Method B cleanup level. TPH concentrations in

two samples exceeded the MTCA Method A cleanup level of 200 mg/kg. Mercury and TPH in soils are discussed further in Section 4.2.3.

### ***Area A8***

Seven soil samples collected in Area A8, the Maintenance Shop Area, were analyzed for inorganics, volatiles, and TPH. The sample locations, analytical results, and comparisons to action levels are presented in Figure 4-38 and Appendix D.

Following is a summary of the soil results for Area A8:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 2.6 to 24.7 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in six samples at concentrations ranging from 23.3 to 391 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in six samples at concentrations ranging from 0.13 to 4.3 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Two volatiles were detected as follows:
  - Methylene chloride—detected in four samples at concentrations ranging from 0.001 to 0.0040 mg/kg, below the action level of 5,330 mg/kg.
  - Toluene—detected in one sample at a concentration of 0.001 mg/kg, below the action level of 64,000 mg/kg.
- **TPH.** TPH was detected in two samples at 151 mg/kg and 338 mg/kg. While there is no MTCA Method C cleanup level for TPH, the MTCA Method A cleanup level for industrial soil is 200 mg/kg. TPH concentrations in one sample exceeded this criterion (A08-06-01 at 338 mg/kg).

**Area A8 Summary:** While metals, volatiles, and TPH were detected, no metals or volatiles exceeded their respective MTCA Method C cleanup levels. TPH was detected in one sample at a concentration above the MTCA Method A cleanup level; TPH in soil is discussed further in Section 4.2.3.

### ***Area A9***

Seven soil samples collected in Area A9, the Non-Process Area, were analyzed for inorganics and volatiles. The sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-39 and Appendix D.

Following is a summary of the soil results for Area A9:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 2.3 to 11.2 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in five samples at concentrations ranging from 22.3 to 1,670 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in three samples at concentrations ranging from 0.16 to 0.94 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Three volatiles were detected as follows:
  - Acetone—detected in one sample at a concentration of 0.012 mg/kg, below the action level of 32,000 mg/kg.
  - Methylene chloride—detected in two samples, both at concentrations of 0.002 mg/kg, below the action level of 5,330 mg/kg.
  - Toluene—detected in two samples at concentrations of 0.012 mg/kg and 0.025 mg/kg, below the action level of 64,000 mg/kg.

**Area A9 Summary:** Metals and volatiles were detected, but no constituent exceeded its respective action level (the MTCA Method C cleanup level). No further sampling was conducted in Area A9 during Round 2.

### *Area A10*

Twenty soil samples collected in Area A10, the Spill Control Reservoir and Sumps, were analyzed for inorganics and volatiles. The sample locations, analytical results, and comparisons to action levels are presented in Figure 4-40 and Appendix D.

Following is a summary of the soil results for Area A10:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in 19 samples at concentrations ranging from 1.2 to 61.4 mg/kg. The concentration of 61.4 mg/kg was detected in one sample (A10MS0301), and this exceeds the action level of 57.1 mg/kg. The concentrations detected in the remaining 18 samples (the maximum was 54.3 mg/kg) were below the action level.

- Copper—detected in all 20 samples at concentrations ranging from 61.7 to 2,580 mg/kg, below the action level of 11,800 mg/kg.
- Mercury—detected in all 20 samples at concentrations ranging from 0.10 to 4.2 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Seven volatiles were detected as follows:
  - 2-Butanone—detected in one sample at a concentration of 0.003 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in two samples at a concentration of 0.002 mg/kg and 0.004 mg/kg, below the action level of 32,000 mg/kg.
  - Carbon disulfide—detected in three samples, all at a concentration of 0.002 mg/kg, below the action level of 32,000 mg/kg.
  - Ethylbenzene—detected in one sample at a concentration of 0.11 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in 10 samples at concentrations ranging from 0.001 to 4.50 mg/kg, below the action level of 64,000 mg/kg.
  - Trichloroethene—detected in five samples at concentrations ranging from 0.001 to 0.009 mg/kg, below the action level of 3,640 mg/kg.
  - Xylene (total)—detected in six samples at concentrations ranging from 0.001 to 0.41 mg/kg, below the action level of 640,000 mg/kg.

**Area A10 Summary:** None of the constituents detected exceeded its respective action level (the MTCA Method C cleanup level), with the exception of arsenic in one sample. No further sampling was conducted in Area A10 because the widespread distribution of arsenic in surface and subsurface soils at the Facility and in the vicinity has already been established. A discussion of the regional occurrence of arsenic is presented in Appendix J.

#### 4.2.2 Surface and Subsurface Soil Samples

Soil samples were collected from Areas A2, A4, A5, A7, and BG during Round 1. The number of samples collected and analyzed for each area ranged from seven to 36. Samples were collected from both surface and subsurface depth intervals during Round 1 in all the areas except A5. Surface soil is defined as the first soil encountered following the removal of asphalt or concrete paving, debris, or grass at each location (see Section 2.3.1). Initially, during Round 1, only surface soil samples were collected from Area A5; in Round 2, additional samples from both the surface and subsurface soil zones in the area were collected and analyzed.

The detected constituents of concern within each investigation area and comparisons with their respective action levels are presented in the following subsections.

### *Area A2*

Thirty-six soil samples collected from 14 sampling locations in Area A2, the Vanillin Production Area, were analyzed for inorganics, volatiles, and semivolatiles. Twenty-nine of the samples were analyzed for isopropyl alcohol, and four for formaldehyde. The sample locations, analytical results, and comparisons to action levels are presented in Figure 4-32 and Appendix D.

Following is a summary of the soil results for Area A2:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in 35 samples at concentrations ranging from 1.2 to 5.6 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in 10 samples at concentrations ranging from 33.4 to 563 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in five samples at concentrations ranging from 0.13 to 0.62 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Eight volatiles were detected. The results for the constituents detected most frequently are summarized as follows:
  - 2-Butanone—detected in 12 samples at concentrations ranging from 0.004 to 0.039 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in 17 samples at concentrations ranging from 0.006 to 4.8 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in 34 samples at concentrations ranging from 0.002 to 3,600 mg/kg, below the action level of 64,000 mg/kg.
- **Semivolatiles.** Twenty-four semivolatiles were detected. The results for the constituents detected most frequently are summarized as follows:
  - PAHs—fourteen PAHs were detected. Chrysene, fluoranthene, naphthalene, phenanthrene, phenol, and pyrene were detected most frequently (three to nine times out of 36 samples analyzed). The other PAHs were detected only once or twice in the 36 samples analyzed. None of the PAHs detected exceeded its respective action level.

- Pentachlorophenol—detected in four samples at concentrations ranging from 0.04 to 0.2 mg/kg, below the action level of 333 mg/kg.
- Methyphenols—2-methylphenol and 4-methylphenol were detected in 12 and 13 samples, respectively, at concentrations ranging from 0.082 to 7.5 mg/kg, below the action level of 16,000 mg/kg for each compound.
- **Formaldehyde.** Formaldehyde was detected in all four of the samples analyzed; concentrations ranged from 0.34 to 3.4 mg/kg, below the action level of 64,000 mg/kg.
- **Isopropyl alcohol.** Isopropyl alcohol was detected in one of the 29 samples analyzed at a concentration of 10 mg/kg. There is no MTCA Method C cleanup level for isopropyl alcohol.

**Area A2 Summary:** Toluene was the most frequently detected organic compound in soil, detected in 34 of the 36 samples at concentrations ranging from 0.002 to 3,600 mg/kg. However, none of the samples exceeded the action level (the MTCA Method C cleanup level) for toluene (64,000 mg/kg). Because toluene was identified as a preliminary constituent of concern and because it was detected in groundwater (as discussed in Section 4.3), Figure 4-44 was developed to provide a visual representation of the Round 1 toluene concentrations as a function of depth in Area A2. The figure shows that the concentration of toluene was greater in samples collected from soil borings 09, 11, 12, and 13, which are located in the western portion of the Vanillin Production Area.

While metals, volatiles, semivolatiles, and other constituents (including toluene) were detected in Area A2, none of the concentrations exceeded their respective action levels (the MTCA Method C cleanup levels). No additional samples were collected from Area A2 during Round 2.

#### *Area A4*

Thirty-one soil samples were collected during Round 1 from the 13 HydroPunch sampling locations in Area A4 and analyzed for inorganics, volatiles, and semivolatiles. The Round 1 sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-34 and Appendix D.

During Round 2, two samples were collected from each of two additional borings (A04-30 and A04-31—see Figure 4-34) that were drilled to collect additional soil samples for toluene and total recoverable petroleum hydrocarbon (TRPH) analyses. The additional Round 2 soil sampling was conducted to further evaluate the extent of toluene in soil and mineral oil in the Unsaturated Zone, using TRPH as a possible indicator of petroleum product. The TRPH analyses were conducted to assess the potential presence of LNAPL at the capillary fringe at the base of the Unsaturated Zone. The Round 2 toluene and TRPH results are shown in Table 4-13.

Following is a summary of the Round 1 soil results for Area A4:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all 31 samples at concentrations ranging from 0.98 to 6.8 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in 18 samples at concentrations ranging from 8.5 to 75 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in three samples at concentrations ranging from 0.27 to 0.4 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Ten volatiles were detected. The results for the constituents detected most frequently are summarized as follows:
  - 2-Butanone—detected in 11 samples at concentrations ranging from 0.005 to 1.1 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in 23 samples at concentrations ranging from 0.007 to 13 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in 28 samples at concentrations ranging from 0.001 to 4,900 mg/kg, below the action level of 64,000 mg/kg.
- **Semivolatiles.** Twenty-four semivolatiles were detected. The results for the constituents detected most frequently are summarized as follows:
  - PAHs—fifteen PAHs were detected. Benz(a)anthracene, benzo(a)pyrene, chrysene, fluoranthene, naphthalene, phenanthrene, 2-methylnaphthalene, and pyrene were detected most frequently (three to five times out of 31 samples analyzed). The other PAHs were detected only once or twice in the 31 samples analyzed. None of the PAHs detected exceeded its respective action level.
  - Pentachlorophenol—detected in six samples at concentrations ranging from 0.055 to 4.8 mg/kg, below the action level of 333 mg/kg.
  - Vanillin—detected in one sample at a concentration of 0.68 mg/kg. There is no MTCA Method C cleanup level for vanillin.
  - Methylphenols—2-methylphenol and 4-methylphenol were detected eight and 10 times, respectively, in the 31 samples analyzed. Concentrations ranged from 0.04 to 5.7, mg/kg, below the action level of 16,000 mg/kg for each compound.

- Bis(2-ethylhexyl)phthalate—detected in 12 samples at concentrations ranging from 0.051 to 6.8 mg/kg, below the action level of 2,860 mg/kg.

The most frequently detected compound in Area A4 was toluene, which was detected in 28 of the 31 samples analyzed with concentrations ranging from 0.001 to 4,900 mg/kg. Because toluene was identified as a preliminary constituent of concern, and because it was detected in groundwater (as discussed in Section 4.3), Figure 4-44 was developed to provide a visual presentation of the Round 1 toluene concentration as a function of depth for soil in Area A4. The figure shows that the concentration of toluene is generally greater in samples taken from 5 feet bgs than from shallower depths, particularly for samples collected from soil borings A04-01 through A04-07.

As discussed earlier, two samples were collected in Round 2 from each of the soil borings A04-30 and A04-31, in order to further assess the extent of toluene and mineral oil (as indicated by TRPH analyses—see Section 2.3.1 for a discussion of the TRPH method and the distinction between TRPH and TPH). The results are presented in Table 4-13. Consistent with the Round 1 results, toluene was detected in all four of the Round 2 samples. The highest concentration detected was 1.9 mg/kg, below the action level of 64,000 mg/kg.

TRPH was detected in three of the four samples collected from borings A04-30 and A04-31. Where detected, concentrations ranged from 43 to 380 mg/kg. Two TRPH samples (A04-30-02 and A04-31-02) were collected at depths ranging from 10 to 13 feet bgs, the approximate depth of the capillary fringe and the depth where LNAPL floating on the capillary fringe would occur if present. Of these two, TRPH was not detected in sample A04-30-02 and was detected at 43 mg/kg in sample A04-31-02. This detected concentration is relatively low and is inconsistent with a floating LNAPL condition where the soil pore space is saturated with oil.

**Area A4 Summary:** While metals, volatiles, and semivolatiles were detected in Area A4, none of the concentrations exceeded its respective action level (the MTCA Method C cleanup level). TPH (as indicated by TRPH analyses) was detected in three of the four samples analyzed. While there is no MTCA Method C cleanup level for TPH, the MTCA Method A cleanup level for TPH is 200 mg/kg. TPH concentrations in one sample exceeded this criterion (A04-31-01 at 380 mg/kg). TPH in soil is discussed further in Section 4.2.3.

### ***Area A5***

Seven surface soil samples collected in Area A5, the Tank Farm, were analyzed during Round 1 for inorganics, volatiles, pesticides/PCBs, and formaldehyde. Three of the seven samples were analyzed for semivolatiles. The Round 1 sampling locations, analytical results, and comparisons to action levels are presented in Figure 4-35 and Appendix D.



During Round 2, 11 samples were collected from five additional borings (Borings A05-10 through A05-14—see Figure 4-35) that were drilled to collect additional soil samples for toluene and TRPH analyses. As described earlier under Area A4, the additional Round 2 soil sampling was conducted to further evaluate the extent of toluene in soil and mineral oil in the Unsaturated Zone. The Round 2 toluene and TRPH results are shown in Table 4-13.

Following is a summary of the Round 1 soil results for Area A5:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all seven samples at concentrations ranging from 0.5 to 6.4 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in five samples at concentrations ranging from 49.6 to 749 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in two samples at concentrations ranging from 0.29 to 0.4 mg/kg, below the action level of 96 mg/kg.
- **Volatiles.** Four volatiles were detected. 2-Butanone, carbon disulfide, and trichloroethene were each detected once at concentrations well below their action levels. Toluene was detected in three of the samples at concentrations ranging from 0.003 to .044 mg/kg, below the action level of 64,000 mg/kg.
- **Pesticides.** Thirteen pesticides were detected as shown in Figure 4-35. 4,4-DDD, 4,4-DDE, 4,4-DDT, endosulfan II, endrin, and endrin aldehyde were detected in four of the seven samples analyzed. The other pesticides were detected in less than one-half the samples. None of the pesticides detected exceeded its respective action level.
- **PCBs.** Aroclor-1254 was detected in one sample at 0.65 mg/kg, below the action level of 5.19 mg/kg.
- **Formaldehyde.** Formaldehyde was detected in all seven samples at concentrations ranging from 0.049 to 3.3 mg/kg, below the action level of 64,000 mg/kg.
- **Semivolatiles.** Eight semivolatiles were detected. The results are summarized as follows:
  - Bis(2-ethylhexyl)phthalate—detected in two of the three samples collected at concentrations 0.044 mg/kg in both samples, below the action level of 2,860 mg/kg.

- PAHs—Seven PAHs were detected in one of the three samples collected (sample A05-07-01). Benz(a)anthracene, benzo(a)pyrene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene were detected at concentrations less than their respective action levels.

As discussed earlier, 11 samples were collected from five borings during Round 2 to further assess the extent of toluene and mineral oil (as indicated by TRPH analyses). The sampling depth intervals varied from a minimum of 0 to 2 feet to a maximum of 11 to 13 feet. The results are presented in Table 4-13. Consistent with the Round 1 results, toluene was detected in most of the samples (nine) at concentrations ranging up to 29 mg/kg, below the action level of 64,000 mg/kg.

TRPH was detected in only one sample (sample A05-10-02, at a depth interval of 3 to 5 feet—see Figure 4-35 and Table 4-13), at a concentration of 8,200 mg/kg. Four of the 11 samples analyzed for TRPH were collected from or near the capillary fringe (at depths of 10 to 13 feet). No detectable TRPH was identified in any of these samples, suggesting that a floating LNAPL condition does not exist at these locations.

**Area A5 Summary:** While metals, volatiles, pesticides, PCBs, and semivolatiles were detected in Area A5, none of the concentrations exceeded its respective action level (the MTCA Method C cleanup level). TPH (as indicated by TRPH analyses) was detected in one of the 11 Round 2 samples. While there is no MTCA Method C cleanup level for TPH, the MTCA Method A cleanup level for TPH is 200 mg/kg. The concentration of the single TPH detection exceeded this criterion (A05-10-02 at 8,200 mg/kg). TPH in soil is discussed further in Section 4.2.3.

### *Area A7*

Thirteen soil samples collected from seven locations in Area A7, the Former Railroad Loading/Unloading Area, were analyzed for inorganics and volatiles. The sample locations, analytical results, and comparisons to action levels are presented in Figure 4-37 and Appendix D.

Following is a summary of the soil results for Area A7:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all 13 samples at concentrations ranging from 0.98 to 7.0 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in seven samples at concentrations ranging from 45.9 to 269 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in seven of the 13 samples at concentrations ranging from 0.13 to 6.4 mg/kg, below the action level of 96 mg/kg.

- **Volatiles.** Six volatiles were detected as follows:
  - 2-Butanone—detected in three samples at concentrations ranging from 0.004 to 0.013 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in nine samples at concentrations ranging from 0.003 to 0.083 mg/kg, below the action level of 32,000 mg/kg.
  - Carbon disulfide—detected in one sample at a concentration of 0.006 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in two samples at concentrations of 0.001 mg/kg and 0.047 mg/kg, below the action level of 64,000 mg/kg.
  - Trichloroethene—detected in one sample at a concentration of 0.001 mg/kg, below the action level of 3,640 mg/kg.

**Area A7 Summary:** While detectable levels of metals and volatiles occurred, none exceeded its respective action level (the MTCA Method C cleanup level). No further sampling was conducted in Area A7 during Round 2.

### ***Area BG***

Fourteen soil samples were collected at seven locations in Area BG, the Background Area, and analyzed for inorganics, volatiles, semivolatiles, and formaldehyde. The sample locations, analytical results, and comparisons to action levels are presented in Figure 4-41 and Appendix D.

Following is a summary of the soil results for Area BG:

- **Inorganics.** Arsenic, copper, and mercury were detected as follows:
  - Arsenic—detected in all 14 samples at concentrations ranging from 1.85 to 10.4 mg/kg, below the action level of 57.1 mg/kg.
  - Copper—detected in two samples at concentrations ranging from 7.3 to 17.4 mg/kg, below the action level of 11,800 mg/kg.
  - Mercury—detected in one sample at a concentration of 0.12 mg/kg, below the action level of 96 mg/kg.

- **Volatiles.** Three volatiles were detected as follows:
  - 2-Butanone—detected in two samples at concentrations of 0.0040 mg/kg and 0.018 mg/kg, below the action level of 192,000 mg/kg.
  - Acetone—detected in three samples at concentrations ranging from 0.003 to 0.087 mg/kg, below the action level of 32,000 mg/kg.
  - Toluene—detected in all 14 samples at concentrations ranging from 0.001 to 0.018 mg/kg, below the action level of 64,000 mg/kg.
- **Semivolatiles.** Three semivolatiles were detected as follows:
  - PAHs—eleven PAHs were detected in one sample, and five of the same PAHs were detected in another sample. The PAHs detected were anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(ghi)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, and pyrene. The detected concentrations for PAHs were all below their respective action levels.
  - Bis(2-ethylhexyl)phthalate—detected in three samples at concentrations ranging from 0.06 to 1.1 mg/kg, below the action level of 2,860 mg/kg.
  - Carbazole—detected in one sample at a concentration of 0.053 mg/kg, below the action level of 2,000 mg/kg.
- **Formaldehyde.** Formaldehyde was detected in all 14 samples at concentrations ranging from 0.26 to 15 mg/kg, below the action level of 64,000 mg/kg.

**Area BG Summary:** While metals, volatiles, and semivolatiles were detected, none exceeded its respective action level (the MTCA Method C cleanup level). Both arsenic and PAHs were detected in Area BG; this was not unexpected because it has been established that arsenic and PAHs are present throughout the region and are not related to past activities at the RPI Facility (see Appendix J).

#### 4.2.3 Soil Investigation Summary

As discussed in Section 2.1, the RFI Workplan identified and discussed a number of preliminary chemicals of concern based on past Facility practices and historical data collected by Dames & Moore (1986) and Landau Associates (1991). The RFI soil sampling and analytical program was tailored to evaluate the presence and extent of these constituents.

The preliminary constituents of concern for soil included arsenic, formaldehyde, PAHs, PCBs, vanillin, and toluene. Although these constituents were detected in a number of soil samples analyzed in Round 1 of the RFI, the action level (the MTCA Method C cleanup

level) was not exceeded for any of these constituents, with one exception for arsenic. Arsenic was detected in one sample collected from Area A10 at a concentration (61.4 mg/kg) that slightly exceeds the action level of 57.1 mg/kg. Arsenic is known to be present regionally at elevated concentrations, and an exceedance of the MTCA Method C cleanup level is consistent with conditions at other sites in the vicinity of the RPI Facility and in the region generally (see Appendix J).

The only other constituent detected above action levels was mercury, which was not cited as a preliminary constituent of concern because its use was not associated with past practices at the Facility. Mercury was found to be present in one Round 1 sample from Area A6 (sample A06-03—see Figure 4-43) at a concentration (268 mg/kg) exceeding the action level of 96 mg/kg. During Round 2, 38 additional samples from the immediate vicinity of that sample were analyzed for the purpose of confirming the Round 1 mercury result and to identify its potential extent. Neither the action level nor the more restrictive MTCA Method B cleanup level for mercury was exceeded in any of the 38 samples analyzed during Round 2. Based on the results of the intensive Round 2 sampling and analysis program, mercury was not identified at concentrations exceeding the action level, and the Round 1 exceedance could not be confirmed. Therefore, the single Round 1 exceedance of the mercury action level is considered an anomalous result and does not warrant further investigation or action.

The possible presence of a significant LNAPL layer (consisting primarily of mineral oil) in Area A4 was also identified as a potential concern in the RFI Workplan. The RFI soil and groundwater investigations were designed to identify LNAPL present at saturation, or near-saturation, levels in the soil pore space. The soil sampling results (based on TRPH data collected during Round 2 in Areas A4 and A5) indicate that the soil pore space does not contain the large quantities of petroleum product that would be characteristic of a floating LNAPL condition. This finding is consistent with the findings of the groundwater investigation (see Section 4.3.4) and the LNAPL monitoring program that is conducted monthly at onsite monitoring wells as an Interim Measure at the Facility.

Data for soil samples collected from the Background Area (Area BG) were also compared to data collected from the other 10 soil investigation areas. Table 4-14 presents a summary of this comparison for selected constituents. As discussed in the RFI Workplan, one objective of the soil investigation in Area BG was to assess the presence of arsenic and PAHs that may represent background conditions (i.e., conditions not attributable to past operations at the Facility). Pre-RFI investigations had indicated the presence in soil of arsenic and the PAHs benzo(a)pyrene, chrysene, benz(a)anthracene, and benzo(k)fluoranthene, none of which was associated with past Facility activities. A comparison of the RFI soil data for Area BG with RFI data for the other areas showed that:

- Arsenic was detected in Area BG at concentrations that were comparable to the concentrations detected in the other 10 areas. These findings are consistent with the belief that arsenic is a regional background constituent (as discussed in detail in Appendix J) and its presence is not attributable to Facility activities.

- PAHs were also detected in Area BG, but at a lower frequency and a slightly lower average concentration. Like arsenic (and as discussed in Appendix J), PAHs are also known to be present regionally in soils. Therefore, while PAH concentrations in Area BG were slightly lower than those detected in other areas, these findings are consistent with the belief that PAHs are regional background constituents and are not attributable to Facility activities.

The RFI Workplan also indicated that formaldehyde, while known to have been in limited use at the Facility, was also suspected of being a background contaminant. Formaldehyde detections are also suspect due to historical difficulties in analytical detection methods. The Workplan noted that comparison of formaldehyde detections in Area BG to the other areas where it was known to have been used or stored (Areas A1, A5, and A6) was an objective of the RFI. The analytical results show that formaldehyde was detected at all seven locations in Area BG. A comparison of these results with the results from the other areas indicates that:

- The frequency of detections in Area BG was similar to the frequency in the other areas.
- The maximum and the mean concentrations detected in Area BG were higher than those in any of the other areas where formaldehyde was known to have been used.

These findings suggest that formaldehyde is likely a background contaminant, especially considering the fact that the highest concentrations of formaldehyde were detected in Area BG, where no use or handling of formaldehyde is known to have occurred.

Based on past operations at the Facility, toluene had been identified as the principal constituent of concern, particularly in Areas A2 and A4. Although toluene was not detected anywhere in soil at concentrations that exceeded its action level, toluene was detected above its action level in groundwater (see Section 4.3).

The location, vertical extent, and magnitude of toluene-contaminated soil in Areas A2 and A4 were compared to the location of toluene-contaminated groundwater. This qualitative comparison was conducted to assess whether toluene-contaminated soil might be the source of toluene in groundwater (see Section 4.3). Figure 4-45 is a concentration contour map for toluene in soil in Areas A2 and A4. The area of toluene contamination in Area A2 appears to be centered beneath the former location of the building where toluene/bisulfite extraction was conducted. This is consistent with the fact that, historically, the majority of toluene usage was concentrated in this area. The most contaminated soils are generally present in the upper 7 feet of the subsurface within the Unsaturated Zone, and concentrations generally decrease with depth (see Figure 4-44). Groundwater beneath the Area A2 soil contamination is not affected by toluene based on the groundwater sampling conducted to date (see Section 4.3). This is consistent with the data shown in Figure 4-44 indicating that toluene concentrations decrease with depth

approaching the groundwater table. In addition, the presence of low-permeability layers in the Unsaturated Zone of this area (Figures 4-6 and 4-8) may restrict toluene to shallower depths.

In contrast to Area A2, RFI data indicate that toluene concentrations in soil in Area A4 do not typically decrease with depth. Toluene concentrations in soil at depths below 9 feet, closer to the groundwater table, are similar to the concentrations detected at shallower depths (Figure 4-44). This area of toluene-contaminated soil coincides with the groundwater toluene plume (Figure 4-45) and suggests that the toluene-contaminated soil may be, at least to some extent, the source of toluene in groundwater.

In summary, no constituent detected in soil at the Facility warrants inclusion in a Corrective Measures Study (CMS) because of an exceedance of an action level. Although arsenic and mercury were detected once each at concentrations above their respective action levels, their inclusion in a CMS is not warranted. Arsenic is known to be regionally present at elevated concentrations, and the single exceedance of the action level is consistent with this condition (see Appendix J). Further, the concentration for the sample (61.4 mg/kg) exceeded the action level (57.1 mg/kg) by only a few milligrams per kilogram. An extensive sampling and analysis effort conducted during Round 2 failed to confirm the presence of mercury above its action level in Area A6. In addition, the Round 2 sampling indicated that mercury was not present above the more restrictive MTCA Method B cleanup level.

TPH in soil does not warrant inclusion in a CMS. As discussed earlier, there is no MTCA Method C cleanup level for TPH; however, the MTCA Method A cleanup level is 200 mg/kg. The concentrations of six soil samples collected during the RFI, and analyzed for either TPH or TRPH, exceeded 200 mg/kg. These were:

- Area A3: TPH at 635 mg/kg (A03-02-01)
- Area A4: TRPH at 380 mg/kg (A04-31-01)
- Area A5: TRPH at 8,200 mg/kg (A05-10-01)
- Area A6: TPH at 645 mg/kg (A06-01-01)  
TPH at 227 mg/kg (A06-05-01)
- Area A8: TPH at 338 mg/kg (A08-06-01)

TPH in soil does not warrant inclusion in a CMS for the following reasons:

- The number of samples exceeding the MTCA Method A cleanup level for TPH was relatively small and their locations were widely distributed—no two adjacent samples in an investigation area exceeded the 200 mg/kg MTCA Method A cleanup level.
- With the exception of sample A05-10-01 (TRPH at 8,200 mg/kg), the above-referenced TPH or TRPH concentrations are relatively close to the MTCA Method A cleanup level.

- The TPH or TRPH detected in most of the samples exceeding the MTCA Method A cleanup level is likely associated with food-grade mineral oil and not with the toxic fuels or motor oils that the cleanup level presumes.

With respect to the last item above, the four samples from Areas A4, A5, and A6 exceeding the MTCA Method A cleanup level (Figures 4-34, 4-35, and 4-36) are located in or near areas of the Facility where mineral oil (Penetec oil) has been observed in the Unsaturated Zone. (The nature and presence of the mineral oil are discussed further in Section 4.3.) Sample A05-10-01, the sample with the highest concentration (8,200 mg/kg of TRPH), was collected from the central portion of the area where mineral oil has been documented. Because only food-grade mineral oil was used at the Facility, further action in Areas A4, A5, and A6 for the purpose of addressing TPH in soil is not warranted.

It should also be noted that the mean TPH (or TRPH) concentration for each investigation area is well below the MTCA Method A cleanup level of 200 mg/kg with the exception of Area A5 (the mean is calculated using one-half the detection limit for samples in which TPH or TRPH was not detected). In Area A5, the TRPH result of 8,200 mg/kg at sample location A05-10-01 was the only detection in 11 samples analyzed. This single detection results in a mean of 759 mg/kg and a geometric mean of 26 mg/kg for Area A5.

It should be noted that there are several other constituents detected in soil at the Facility that do not have an MTCA Method C cleanup level (the RFI action level for soil). These include the following seven inorganic compounds: aluminum, calcium, iron, lead, magnesium, potassium, and sodium. Lead was not detected above the MTCA Method A cleanup level of 250 mg/kg in any of the RFI soil samples. The remaining six inorganics are common elements of soil and rock; their presence in Facility soils was expected. Therefore, these seven inorganics do not warrant inclusion in a CMS.

Other detected constituents that do not have MTCA Method C cleanup levels will be addressed in the forthcoming Risk Assessment and Media Cleanup Standards evaluation. If an RFI soil result for such a constituent exceeds the final Media Cleanup Standard, the constituent will be carried forward and addressed in the CMS. Other constituents detected in soil during the RFI that do not have a MTCA Method C cleanup level and are subject to analysis during the Risk Assessment and Media Cleanup Standards evaluation are as follows:

#### Inorganics

Cobalt

#### Pesticides

Endrin

#### Semivolatiles

2-Methylnaphthalene

Benzo(ghi)perylene

Isopropyl alcohol (2-Propanol)

Pentachlorophenol

Phenanthrene

Vanillin



### 4.3 Groundwater Investigation

The RFI groundwater investigation activities consisted of a HydroPunch survey and two rounds of monitoring well sampling. This section describes the results of these activities as follows:

- The analytical results of the HydroPunch and monitoring well sampling efforts are described in Sections 4.3.1 and 4.3.2, respectively. (The complete RFI groundwater quality database of detected results is provided in Appendix D.)
- Section 4.3.3 discusses the extent of toluene contamination based on HydroPunch and monitoring well data.
- Section 4.3.4 summarizes the LNAPL monitoring results.
- Sections 4.3.5 through 4.3.8 address specific topics including miscellaneous organic compounds detected, metals in groundwater, conventional water quality and biological indicator parameters, and the extent of the "Black Liquid" at the Facility.

The action levels for groundwater are the federal MCLs for drinking water (40 CFR Part 131). It should be pointed out, however, that the use of MCLs as action levels is very conservative, since the Upper Aquifer and the Duwamish River are not sources of potable water now, and are not expected to be in the future.

#### 4.3.1 HydroPunch Results

Forty-three HydroPunch groundwater samples were collected during Round 1 of the RFI, from February 25 through April 14, 1994. These samples were collected from 29 borings (Figure 2-19) and were analyzed for the following parameters:

- Volatile organic compounds (benzene, toluene, ethylbenzene, and xylene) by EPA Method 8020
- TPH by WTPH-418.1 (modified)
- TOC by EPA Method 415

The HydroPunch borings were drilled to three different depth ranges:

- Three borings (A04-27, -28, and -29) were drilled to the perching layer (in the Unsaturated Zone) to collect perched groundwater samples for analysis.

- Twenty-two borings were drilled into the upper part of the Upper Aquifer (to a maximum sampling depth of 31 feet) to collect shallow groundwater samples. One or two groundwater samples were collected from each of these borings.
- Four borings were drilled to the lower part of the Upper Aquifer (to a maximum sampling depth of 64 feet bgs). Up to five groundwater samples were collected over the vertical extent of the Upper Aquifer from each of these deeper borings.

The HydroPunch analytical results are presented in Table 4-15. Toluene was detected in 37 of the 43 samples collected at concentrations ranging from 0.6 to 510,000  $\mu\text{g/l}$ . Of these 37 samples, the concentrations of 17 exceeded the action level of 1,000  $\mu\text{g/l}$ , the MCL for toluene. The concentrations in six of the samples exceeded 100,000  $\mu\text{g/l}$ . The extent of toluene contamination is discussed further in Section 4.3.3.

Benzene was detected in seven samples at concentrations ranging from 1 to 62  $\mu\text{g/l}$ , below the action level of 5  $\mu\text{g/l}$ . Ethylbenzene was detected in five samples at concentrations ranging from 0.6 to 74  $\mu\text{g/l}$ , below the action level of 700  $\mu\text{g/l}$ . Xylene was detected in 13 samples at concentrations ranging from 0.9 to 110  $\mu\text{g/l}$ , below the action level of 10,000  $\mu\text{g/l}$ . TPH was detected in 25 of 40 samples at concentrations ranging from 1.13 to 516 mg/l. TOC was detected in all 35 samples analyzed at concentrations ranging from 4.59 to 3,800 mg/l. There is no MCL for TPH or TOC.

An aliquot from the HydroPunch groundwater samples scheduled for laboratory analysis was collected in a separate container for field headspace monitoring (insufficient sample volume prohibited headspace monitoring in many cases). Headspace measurements to detect organic vapors in the headspace of the covered containers were made with a PID. The data are summarized in the scatter chart shown in Figure 4-46 (note that only those samples with both toluene and PID detections are plotted). The scatter chart indicates a relationship between the headspace measurements and toluene data at higher concentrations (e.g., above a toluene concentration of 5,000 to 10,000  $\mu\text{g/l}$ ). A regression analysis of the data yields an R-squared value of 0.78. (The R-squared value is an indicator of the reliability of the regression. The possible values range from 0 [no relationship between the two sets of variables] to 1 [a perfect relationship]). The data indicate that PID headspace measurements can be used as an indicator of high toluene concentrations in groundwater.

TOC, toluene, and TPH data collected during the HydroPunch investigation were assessed to determine if a statistical correlation existed between TOC and toluene or between TPH and toluene. As discussed in the RFI Workplan, this was done to evaluate whether TOC or TPH could be used as a toluene indicator in the event that additional investigations are necessary in the future. The results indicated that there is no apparent correlation between these data (see Table 4-15).

### 4.3.2 Groundwater Monitoring Results

#### *Round 1 Detected Constituents*

Round 1 groundwater sampling was conducted between January 17 and February 28, 1994, at 30 pre-RFI monitoring wells. Analytical parameters included inorganics, volatiles, semi-volatiles, TOC, formaldehyde, and Appendix IX hazardous substance list constituents. The parameters analyzed varied by well and by investigation area, as described in the RFI Workplan. Metal analyses were conducted on both filtered (dissolved) and unfiltered (total) samples. Table 2-8 shows the target parameters by well for Round 1. The locations of the wells sampled during Round 1 are shown in Figure 2-3.

Table 4-16 presents a statistical summary of the Round 1 groundwater results. Shown for each parameter are the detection frequency, minimum and maximum detected concentrations, and the action levels (i.e., the MCLs). Appendix D presents a complete list of all the constituents detected above the laboratory detection limits during Round 1.

#### *Round 2 Detected Constituents*

Round 2 groundwater sampling was conducted between August 24 and September 1, 1994. Nineteen monitoring wells were sampled, and the analytical parameters were selected in order to confirm and/or augment groundwater constituents identified during Round 1. The Round 2 parameters included toluene, TRPH, acetone, methylphenol, bis(2)-chloroethylether, herbicides, antimony, beryllium, and vanadium. These parameters were selected for Round 2 analysis for the following reasons:

- Toluene—With the exception of two wells sampled solely for herbicides and TRPH, samples from all the wells were analyzed for BTEX (Method 8020) or volatiles (Method 8240) in order to confirm and further assess the magnitude and extent of toluene in groundwater.
- TRPH—All Round 2 groundwater samples were analyzed for TRPH to provide additional data on the potential presence and extent of mineral oil previously identified as a floating LNAPL layer in some areas of the Facility.
- Acetone, methylphenol, bis(2)-chloroethylether, beryllium, and vanadium—Analyses were performed on samples from selected wells (see Table 2-11) to confirm the presence and concentrations of these constituents reported during Round 1.
- Herbicides—Samples were collected for herbicide analysis at eight monitoring wells (see Table 2-11). The herbicide analyses were included to complete the Appendix IX analyses conducted in Round 1, as the Round 1 herbicide data acceptance criteria for spike recoveries (see Section 3).

Table 2-11 presents a complete list of the parameters analyzed for each well during Round 2.

Table 4-17 provides a statistical summary of the Round 2 groundwater results. Shown for each parameter are the detection frequency, the minimum and maximum detected concentrations, and the drinking water MCLs that are the action levels for the RFI. Appendix D presents a complete list of all the constituents detected above the laboratory detection limits during Round 2.

Appendix I presents the benzene, toluene, ethylbenzene, and xylene (BTEX) results for the five samples collected from wells H1, MW-13, MW-17, MW-18, and MW-19, discussed in Section 2.4.2. These samples were collected with both Waterra pumps and bailers in order to assess the comparability of BTEX data collected by the two methods. A discussion of the results accompanies the presentation of the data in Appendix I. For consistency and comparability, the groundwater data collected with Waterra pumps are considered the data of record for Round 2.

### *Constituents Exceeding Action Levels*

Tables 4-18 and 4-19 summarize the parameters that exceeded action levels (i.e., MCLs) during Rounds 1 and 2, respectively. Iron and manganese (both soluble and total) exceeded the action levels (secondary MCLs in these cases) in nearly every sample. This is consistent with regional groundwater quality conditions. Iron and manganese concentrations are known to be high in the shallow groundwater of the Duwamish River Valley and the adjacent Kent Valley (*South King County Ground Water Management Plan*, 1991).

The following metals exceeded action levels in unfiltered samples:

- Total (unfiltered) lead (ten exceedances, in wells DM-3A, A9, B2, B5, H9, G1, B1B, G3, E3, and DM-1A)
- Total chromium (seven exceedances in wells B2, DM-5, DM-2A, DM-8, H9, G3, and E3)
- Total arsenic (five exceedances, in wells DM-5, H11, H9, G3, and E3)
- Total beryllium (five exceedances, in wells DM-5, DM-2A, DM-8, G3, and E3)
- Total antimony (one exceedance, in well E3)
- Total cadmium (one exceedance, in well E3)
- Total copper (one exceedance, in well B2)

It should be noted that monitoring wells E3, DM-1A, and DM-1B are located in the Background Area (Area BG).

Metal concentrations in filtered samples that exceeded action levels were fewer in number:

- Beryllium (three exceedances, in wells DM-5, DM-2A, and DM-8)
- Chromium (three exceedances, in wells DM-5, DM-2A, and DM-8)
- Arsenic (one exceedance, in well H9)

Comparison of the total (unfiltered) and filtered metals data indicates that exceedances of action levels for lead, antimony, cadmium, and copper are attributable to solids present in unfiltered samples. As discussed in Section 4.3.6, attention should be focused on dissolved (filtered) metals data for comparison to action levels.

The action level for toluene was exceeded in 14 samples over the two monitoring rounds: three times in Round 1 and 11 times in Round 2. The higher frequency of exceedances during Round 2 is attributable to the fact that eight new monitoring wells were installed in or near the toluene plume during the Round 2 investigation. Only groundwater samples collected from monitoring wells in Areas A4 and A5 were found to exceed the action level for toluene. A detailed discussion of the extent of toluene contamination is presented in Section 4.3.3.

### *Organic Constituents Detected in the Lower Aquifer*

During Round 1, three organic compounds were detected in samples collected from three Lower Aquifer monitoring wells (no action levels were exceeded). This is inconsistent with the hydrogeologic conditions at the Facility that suggest that vertical migration of constituents from the Upper to the Lower Aquifer is unlikely. Investigations of the Facility have demonstrated that a laterally extensive, low-permeability Aquitard separates the Upper and Lower Aquifers and there is an upward vertical hydraulic gradient between the two aquifers. These factors combine to significantly inhibit the vertical migration of constituents from the Upper to the Lower Aquifer.

Acetone, toluene, and bis(2-ethylhexyl)phthalate were detected in Round 1 Lower Aquifer groundwater samples as follows:

- Well DM-1B—Bis(2-ethylhexyl)phthalate (1  $\mu\text{g/l}$ , field duplicate and J-qualified [estimated] result)
- Well DM-3B—Acetone (370  $\mu\text{g/l}$ ), toluene (3  $\mu\text{g/l}$ ), and bis(2-ethylhexyl)phthalate (2  $\mu\text{g/l}$ , J-qualified [estimated] result)
- Well B1B—Toluene (1  $\mu\text{g/l}$ ) and bis(2-ethylhexyl)phthalate (6  $\mu\text{g/l}$ , J-qualified [estimated] result)

It is likely that these compounds were introduced into the Lower Aquifer in the past by contaminated surface water entering the flush-mounted (at the ground surface) wellhead structures. In the case of bis(2-ethylhexyl)phthalate, it is also possible that the PVC monitoring well materials are the source, as this compound is a common PVC plasticizer. Its presence in monitoring wells constructed with PVC screen or casing is not unusual. Bis(2-ethylhexyl)phthalate is also relatively immobile in groundwater, indicating that it has not migrated vertically from the Upper Aquifer. As discussed above, the Facility's hydro-geologic conditions indicate that vertical migration of any of these compounds from the Upper Aquifer to Lower Aquifer is unlikely.

### 4.3.3 Extent of Toluene

The data collected during, and prior to, the RFI indicate that a plume of dissolved toluene is present in the Upper Aquifer in three investigation areas—Areas A4, A5, and A6. Landau Associates detected the plume during their 1991 Facility investigation. At that time, concentrations in groundwater were reported to be up to 330,000  $\mu\text{g/l}$  for three monitoring wells: G5 (now replaced by MW-12), H10, and H11. Trace concentrations of toluene ( $<10 \mu\text{g/l}$ ) were reported by Landau in wells B4 and B6 in Area A2, immediately north-east of the three wells mentioned above.

Based on the concentrations reported by Landau Associates, a HydroPunch investigation was conducted during Round 1 of the RFI to further delineate the magnitude and extent (horizontal and vertical) of the toluene plume. As discussed in Section 4.3.1, 43 HydroPunch groundwater samples were collected from 29 borings. The samples were analyzed for BTEX, TPH, and TOC. Two groundwater sampling events were then conducted during the Round 1 and Round 2 investigations. Round 2 included the installation of eight new monitoring wells in the vicinity of Areas A4, A5, and A6 to better delineate the horizontal and vertical extent of the toluene plume.

The results of the HydroPunch investigation and monitoring well sampling are presented in Section 4.3.1 and Tables 4-15 through 4-20. As discussed earlier, toluene was the organic compound detected most frequently. Benzene, ethylbenzene, and xylene were impurities in the toluene feedstock used by RPI and were also detected, but less frequently and at lower concentrations. These three compounds were detected at or near the toluene plume.

The following sections address the horizontal and vertical extent of the toluene plume as identified by the Round 1 data (from HydroPunch and monitoring well sampling) and Round 2 data (from monitoring well sampling).

#### *Horizontal Extent of Toluene*

Figures 4-47 and 4-48 show concentration contours representing the magnitude and estimated horizontal extent of the toluene plume based on the Round 1 and Round 2 data, respectively. Figure 4-47 is based on a compilation of the Round 1 groundwater monitoring data (collected in January and February 1994) and the HydroPunch data (collected in

February, March, and April 1994). Figure 4-48 shows conditions based on the Round 2 data; the figure includes data for the eight new monitoring wells installed during the Round 2 investigation.

As can be seen from Figure 4-47, the extent of the toluene plume based on the Round 1 monitoring well and Hydropunch data is centered over Area A4 and is located in approximately the same area where the highest concentrations of toluene were detected in soils (see Section 4.2.3 and Figure 4-48). The area inside the 1,000  $\mu\text{g/l}$  contour line is approximately 1.5 acres. Toluene concentrations in the center of the plume are up to several hundred thousand micrograms per liter. Concentration gradients along the outer edges of the plume are relatively steep; for example, concentrations decrease from approximately 500,000  $\mu\text{g/l}$  to trace levels over distances as short as 40 feet.

Figure 4-48 shows concentration contours representing the horizontal extent of toluene based on the Round 2 data. Because the contours represent data from monitoring wells only, and not from HydroPunch data, the number of data points is fewer than that shown in Figure 4-47.

A comparison of the results of Rounds 1 and 2 indicates that the configuration of the plume (as shown in Figures 4-47 and 4-48) is consistent. The shape and size of the plume indicated by the Round 2 data are similar to those depicted by the Round 1 data. Like the Round 1 data, the Round 2 data indicate that toluene concentrations in the center of the plume are up to several hundred thousand micrograms per liter (the maximum toluene concentration is 340,000  $\mu\text{g/l}$  at well H11). Also, the concentration gradients remain relatively steep along the outer edge of the plume.

### *Vertical Extent of Toluene*

Most of the groundwater samples collected during the Round 1 HydroPunch investigation were collected within the upper 15 feet of the Upper Aquifer. However, a number of samples were collected from greater depths in the aquifer to characterize the vertical distribution of toluene. These deeper samples were collected from HydroPunch borings including A04-06, A04-14, A04-23, and A05-24. Data from these borings (see Table 4-15) indicate that toluene is present throughout the vertical extent of the Upper Aquifer, but concentrations in the lower half of the aquifer are typically two to three orders of magnitude lower than near the top of the aquifer. Boring A05-24, drilled near the center of the toluene plume, is an exception; toluene concentrations at this location were found to increase with depth to a maximum of 94,000  $\mu\text{g/l}$  at a depth of 62 feet bgs. In contrast, the deepest toluene samples collected from HydroPunch borings A04-06, A04-14, and A04-23 ranged from 5 to 960  $\mu\text{g/l}$ , which does not exceed the action level and is two to three orders of magnitude below concentrations in the upper part of the Upper Aquifer.

After installation of the eight new monitoring wells during Round 2, the groundwater monitoring network in the toluene plume area included three wells screened near the bottom of the Upper Aquifer (wells H1, MW-13, and MW-16—see Figure 4-48). Each well is

located within a few feet of a well screened across the groundwater table in the Upper Aquifer (wells H10, H11, and MW-15, respectively). Therefore, paired wells H10/H1, H11/MW-13, and MW-15/MW-16 represent locations where the vertical extent of toluene in the Upper Aquifer can be assessed at a single location.

Figures 4-49 and 4-50 show the estimated vertical extent of toluene contamination. These cross-sections depict both Round 1 HydroPunch data and Round 2 monitoring well data, with the following exception: Data from HydroPunch boring A05-24 are not shown because Round 2 monitoring well MW-16 is drilled in the same location (within a few feet). The toluene result from well MW-16 (1,100  $\mu\text{g/l}$ ) is shown because it is more recent, it was collected from a monitoring well that was properly constructed and developed, and it is consistent with concentrations detected in other samples collected from the lower half of the Upper Aquifer.

As can be seen from Figures 4-49 and 4-50, toluene was detected across the vertical extent of the Upper Aquifer in the central portion of the plume. The highest toluene concentrations (up to 480,000  $\mu\text{g/l}$ ) are in the upper 20 feet of the aquifer. Concentrations in the lower half of the aquifer range from 110 to 1,200  $\mu\text{g/l}$  (in wells H1, MW-13, and MW-16, and in HydroPunch boring A04-23).

It should be noted that during Round 2, toluene was detected in well H1 for the first time; previous data for this well (from Landau Associates and Round 1 of the RFI) did not indicate any toluene. Therefore, the Round 2 result for well H1 is considered provisional and will require confirmation in the next groundwater monitoring event.

#### 4.3.4 LNAPL Occurrence

LNAPL has been noted in several borings and wells at the Facility over the past 4 years. LNAPL was first detected atop the groundwater surface in monitoring well G5, a 2-inch-diameter monitoring well installed by Landau Associates in 1991.

RPI undertook work to evaluate and remove LNAPL from the Facility in the summer and fall of 1992 as an Interim Measure. In August 1993, RPI abandoned well G5 and replaced it with a 4-inch-diameter well to facilitate recovery of the LNAPL. The replacement well (MW-12) was installed approximately 8 feet west of well G5. In the months prior to its abandonment, the LNAPL thickness in well G5 ranged from 0.1 foot to 2.3 feet. Monitoring of MW-12 in the first few months after its installation indicated LNAPL thicknesses ranging from approximately 1.0 to 2.7 feet. Also, up to 0.2 foot of LNAPL was noted in well H10 in September 1993.

The characteristics of the LNAPL were identified in pre-RFI laboratory tests conducted in the spring of 1993 using a sample collected from well G5. The tests compared the LNAPL with commercial Penetec oil (a white food-grade mineral oil) formerly used in vanillin production at the Facility. The results indicated that the LNAPL had a specific gravity of 0.815 and included approximately 82 percent Penetec oil and 11 percent toluene. The



remaining 7 percent of the LNAPL could not be precisely identified analytically, but was qualitatively identified as Penetec oil and toluene degradation products.

As discussed in Sections 2.4.1 and 2.4.3, work was conducted during the RFI to further assess the extent of the LNAPL. This was accomplished in two ways:

1. A temporary well screen was installed at the groundwater table at the 29 HydroPunch boring locations. After allowing time for water and LNAPL (if present) to enter the well screen, the screen contents were sampled with a transparent bailer (see Section 2.4.1 for further discussion of the methodology).
2. The extent of the LNAPL was assessed by periodic monitoring of Upper Aquifer monitoring wells. This was accomplished by lowering a transparent bailer partway through the liquid surface in each well and examining the recovered sample for the presence of immiscible liquid (see Section 2.4.2).

The results of both types of monitoring are discussed below. The locations of the borings and monitoring wells where LNAPL has been observed are shown in Figure 4-51.

LNAPL was encountered in three of the 29 HydroPunch borings drilled during the RFI (borings A04-08, A05-24, and A04-01—see Figure 4-51). LNAPL was observed in HydroPunch bailer samples recovered from A05-24 and A04-01, but not in the bailer sample recovered from boring A04-08. However, LNAPL was noted during drilling as evidenced by an oil coating on the drilling rods.

All the Upper Aquifer monitoring wells screened across the groundwater table (31 wells) have been monitored for LNAPL. Of these, wells located in the vicinity of MW-12 and the Tank Farm have been monitored periodically since late 1993. The monitoring results through December 1994 are presented in Table 4-21. Multiple measurements taken in individual wells on the same day indicate that LNAPL thickness varies with groundwater-level fluctuations (see March 10, 11, and 17, 1994 data for well H10 in Table 4-21). As can be seen from Table 4-21, LNAPL has been noted as "film" or "sheen" or measured at very low thicknesses at least once in the following eight monitoring wells since late 1993: H1, H6, H9, H10, H11, MW-12, MW-15, and MW-19. In September 1994, oily sheens were observed in wells H9 and H6, the first time LNAPL had been observed in these wells. An LNAPL thickness of 0.12 foot was also observed in well MW-H11 at that time, the thickest accumulation of oil reported for this well.

There has been a trend of decreasing LNAPL volume in those wells where significant thicknesses have been noted in the past (e.g., MW-12 and H10). The LNAPL in wells MW-12 and H10 has dissipated to trace quantities (i.e., a film or sheen on the water surface). Several LNAPL recovery devices (passive and pneumatic hydrophobic membrane devices) have been installed in wells MW-12 and H10 since the summer of 1993. During October and through December 1993, a passive skimmer was used in well MW-12 to recover LNAPL. In October 1993, prior to the recovery effort, there were approximately

14 inches of LNAPL in MW-12. By December 1993, the thickness had been reduced to approximately 2 inches. Approximately 30 gallons of LNAPL were recovered from well MW-12 during this three-month period. With increasing thicknesses of LNAPL observed in well H10 in March 1994, a pneumatic skimmer was installed and operated until April 11. Similar recovery rates and volumes resulted, with a total of less than one gallon of LNAPL removed over a period of 2-1/2 weeks. Nearly all the LNAPL removed was collected in the first few days of this period.

The installation of new monitoring wells during Round 2 (August 1994) provided several new LNAPL monitoring locations in the vicinity of the Tank Farm. LNAPL has been observed in two of these wells: MW-15 and MW-19. LNAPL was observed in HydroPunch borings near the MW-15 and MW-19 locations; therefore, the occurrence of LNAPL in wells screened across the groundwater table at these locations is consistent with the HydroPunch findings. Of these, the maximum thickness of 0.021 foot was detected at MW-15 (September 1994) and MW-19 (October 1994).

Based on the field investigations and recovery efforts conducted before and during the RFI, it does not appear that a large volume of LNAPL is present beneath a large area of the Facility. LNAPL monitoring has been conducted at approximately 40 locations to date in the vicinity of former monitoring well G5 (now replaced by well MW-12) where Landau Associates first detected LNAPL in 1991. In spite of the significant efforts that have been made to identify and characterize the extent of LNAPL at the Facility, it has been detected at only a few locations, and only intermittently. Attempts to correlate LNAPL presence with other data (e.g., TRPH results for soil) are inconclusive. The most recent LNAPL monitoring data collected on December 5, 1994 (Table 4-21 and Figure 4-51), show only a film, and only in one well. This indicates that there is only a small, unrecoverable volume of LNAPL distributed across a limited area of the Facility. The sporadic detections of LNAPL in a few Facility monitoring wells indicate that LNAPL may be present within the capillary fringe, but at residual saturation levels that generally render it undetectable and immobile under most conditions.

Monthly LNAPL monitoring and documentation are continuing at the Facility as an Interim Measure.

#### **4.3.5 Miscellaneous Organic Compounds**

A number of organic compounds were detected in RFI groundwater samples infrequently and at relatively low concentrations. These are discussed below.

##### ***Semivolatile Organic Compounds***

Semivolatiles detected in the RFI groundwater samples and not addressed previously are discussed below.

**PAHs.** PAHs were detected in a number of groundwater samples. With one exception of benzo(a)pyrene (discussed below), none of the PAH concentrations exceeded their respective action level (i.e., MCL). (Note that MCLs have not been established for all PAH compounds.) PAHs are characterized by low solubilities and high partition coefficients. As such, they tend to have a high affinity for the aquifer matrix and low mobility in groundwater. Based on these characteristics, it is likely that many of the PAHs detected in RFI groundwater samples were sorbed to the suspended solids present in the samples rather than dissolved in the aqueous phase. Based on historical Facility information, PAHs were never used in manufacturing at the Facility. Landau Associates (1991) reported a number of PAH detections in both soil and groundwater. It is also known that PAHs are widely distributed across the site and throughout the region, as discussed in Appendix J. Therefore, while detection of PAHs in groundwater at the Facility is not unexpected, PAHs are not associated with Facility operations and are not considered constituents of concern.

Benzo(a)pyrene exceeded the action level of 0.2 µg/l in Round 1 samples from four monitoring wells as follows:

- DM-2A (1 µg/l)
- DM-5 (6 µg/l)
- G3 (2 µg/l)
- H11 (7 µg/l)

All the above data are J-qualified (estimated values).

**Bis(2-chloroethyl)ether.** Bis(2-chloroethyl)ether was detected in Round 1 and 2 groundwater samples from well A2 at concentrations of 2 and 5 µg/l (both are J-qualified [estimated] values). Bis(2-chloroethyl)ether is a carcinogen, but there is no MCL for this compound. In the absence of an MCL value with which to establish an action level, these detections were compared to the MTCA Method C groundwater cleanup level of 21 µg/l. Both concentrations are well below the MTCA Method C groundwater cleanup level of 21 µg/l.

**Pentachlorophenol.** Pentachlorophenol was detected in one groundwater sample above the action level of 1 µg/l. The pentachlorophenol concentration in the Round 1 sample from well H10 was 5 µg/l (J-qualified [estimated] value). Pentachlorophenol was used at the Facility, but its detection in only one well indicates that this is an isolated occurrence.

**2-Methylphenol and 4-Methylphenol.** Both 2-methylphenol and 4-methylphenol were detected in groundwater samples collected in both Rounds 1 and 2. Both compounds were detected in Round 1 in samples from wells H10, H11, and MW-12; the concentrations ranged from 210 to 1,900 µg/l for 2-methylphenol and 130 to 1,600 µg/l for 4-methylphenol. All three of these wells are located in the core of the toluene plume area. Wells H11 and MW-12 were sampled again in Round 2 for semivolatile organics. Both 2-methylphenol and 4-methylphenol were confirmed in both wells H11 and MW-12; the

concentrations were 1,800 and 74  $\mu\text{g/l}$  for 2-methylphenol and 1,100 and 13  $\mu\text{g/l}$  (J-qualified or estimated) for 4-methylphenol, respectively. There is no MCL or MTCA Method C cleanup level for either compound.

**Bis(2-ethylhexyl)phthalate.** Bis(2-ethylhexyl)phthalate was detected 14 times in Round 1 and one time in Round 2. Concentrations ranged from 1 to 53  $\mu\text{g/l}$  in Round 1 (13 of the 14 Round 1 detections were J-qualified or estimated); the Round 2 result (well MW-12) was 32  $\mu\text{g/l}$ . As with bis(2-chloroethyl)ether, there is no MCL for bis(2-ethylhexyl)phthalate, so the MTCA Method C cleanup level of 62.5  $\mu\text{g/l}$  was used for comparison. All detections fell below the MTCA Method C level. Three of the 14 Round 1 detections occurred in samples collected from Lower Aquifer wells, as described earlier in Section 4.3.2.

Also as discussed in Section 4.3.2, the source of the bis(2-ethylhexyl)phthalate may be the monitoring well screen and casing, as this compound is a common plasticizer used in PVC. Its presence in monitoring wells constructed with PVC screens or casing is not unusual. Bis(2-ethylhexyl)phthalate is also relatively immobile in groundwater, indicating that it has not migrated vertically from the Upper Aquifer. As discussed above, the hydrogeologic conditions at the Facility also indicate that vertical migration of any of these compounds from the Upper Aquifer to the Lower Aquifer is unlikely.

**Vanillin.** Vanillin, which was produced at the Facility, was detected in 10 groundwater samples during Round 1. The concentrations ranged from 1 to 35  $\mu\text{g/l}$  (7 of the 10 detections were J-qualified [estimated]). All the detections were in the Upper Aquifer. The three highest concentrations (5 to 35  $\mu\text{g/l}$ , not J-qualified) were in wells DM-2A, DM-7, and DM-8. These wells are located around the perimeter of the Tank Farm. There is no MCL or MTCA Method C cleanup level for vanillin.

### *Volatile Organic Compounds*

Volatiles detected in the RFI groundwater samples and not addressed previously are discussed below.

**Methylene Chloride.** Methylene chloride was detected in Round 1 at 57  $\mu\text{g/l}$  at well H11, above the action level of 5  $\mu\text{g/l}$ . Although methylene chloride is a common laboratory contaminant, and may have been introduced during sample bottle preparation, sample collection, sample transport, or cross-contamination in the laboratory, the QA/QC data do not confirm this. Given this and its historical detection at the Facility, methylene chloride appears to be present in groundwater and is not necessarily caused by laboratory contamination of the samples.

**Benzene.** Benzene was detected during Round 1 at wells DM-7, B5, and H11 at concentrations of 2, 5, and 230  $\mu\text{g/l}$ , respectively. During Round 2, benzene was detected at well B6 at 0.8  $\mu\text{g/l}$  and again at DM-7 at 1  $\mu\text{g/l}$ . Only one of these detections (H11)

exceeded the action level of 5  $\mu\text{g/l}$ . Benzene was detected in H11 during Round 2 but could not be quantified due to matrix interference.

**Acetone.** Acetone was detected during Round 1 at wells H11 and DM-3B (a Lower Aquifer well) at concentrations of 56,000 and 370  $\mu\text{g/l}$ , respectively. The acetone detection in well DM-3B is addressed in the discussion of constituents detected in the Lower Aquifer (Section 4.3.2). The source of the acetone is unknown, but may be due to the past use of isopropyl alcohol onsite because acetone is an oxidation product of isopropyl alcohol. There is no MCL for acetone; however, the detection at well H11 exceeds the MTCA Method C cleanup level of 17,500  $\mu\text{g/l}$ . Like benzene, acetone was detected in H11 during Round 2 but could not be quantified due to matrix interference.

**Formaldehyde.** Formaldehyde was detected in 16 of 17 groundwater samples during Round 1. Formaldehyde is associated with historical Facility practices and its presence was not unexpected. The concentrations ranged from 32 to 450  $\mu\text{g/l}$ . The three highest concentrations (ranging from 290 to 450  $\mu\text{g/l}$ ) were at wells DM-4, A4, and A9 located around the Distribution Center. There is no MCL or MTCA Method C cleanup level for formaldehyde.

**2-Butanone.** 2-butanone (methyl ethyl ketone) was detected once in Round 1, at well H10 at a concentration of 1,300  $\mu\text{g/l}$ . It was also detected during Round 2 at well H11, but could not be quantified due to matrix interference. The source of the 2-butanone is unknown. There is no MCL or MTCA Method C cleanup level for 2-butanone.

#### 4.3.6 Metals in Groundwater

This section focuses on metals detected in groundwater at the Facility. Many of the metals detected in monitoring well samples are not of particular concern as they are present naturally in groundwater. These are not considered contaminants when present at normal concentrations. Certain metals were detected, however, that may originate from anthropogenic sources as evidenced by their absence or low concentrations at upgradient monitoring wells (e.g., wells in Area BG). Other metals, such as chromium and copper, are also addressed here because of their toxicity to marine organisms and their potential introduction to the Duwamish Waterway via groundwater discharge. Chromium, in particular, requires discussion as its oxidation state determines its toxicity to both humans and marine organisms.

Analyses of groundwater sampling locations for metals were performed with unfiltered and filtered samples. Unfiltered samples contain both particulate and dissolved forms, whereas filtered samples contain only the dissolved form.

Particulate matter that can be removed by filtration is virtually always immobile in migrating groundwater; whereas constituents that pass through a filter have the potential to migrate as groundwater moves through the aquifer. Therefore, from the standpoint of a potential release from the Facility by means of groundwater transport and comparison to action levels, attention should be focused on dissolved (filtered) metal data.

Two metals were detected only in the Background Area (Area BG). These metals, antimony and cadmium, were detected in an unfiltered sample from well E3 at concentrations of 69.3 and 8.1  $\mu\text{g/l}$ , respectively (the action levels are 6 and 5  $\mu\text{g/l}$ , respectively). Therefore, antimony and cadmium are not considered constituents of concern because they were detected at the upgradient end of the Facility and the data indicate that their detection is associated with sediment in the sample (these two metals were not detected in filtered samples).

Three other dissolved metals—beryllium, copper, and chromium—were found in Area BG and non-background areas at concentrations exceeding action levels (see Section 4.3.2 and Table 4-16). Beryllium was never used at the Facility, and it has been found at other sites along the Duwamish Waterway. Both of these facts indicate that this metal is not associated with activities at the Facility.

Copper was detected at a number of wells in both Area BG and non-background areas. However, only one sample exceeded the action level of 1,300  $\mu\text{g/l}$  (an unfiltered sample from well B2 at 4,290  $\mu\text{g/l}$ ). Unlike beryllium, copper has been used in production processes at the Facility. Copper is not considered a constituent of concern as the only exceedance of the action level is associated with an unfiltered sample.

As is discussed in Section 4.3.8 and as shown in Figure 4-52, there is a correlation between the occurrence of dissolved chromium in the Upper Aquifer and the presence of Black Liquid, although there are some exceptions to this association. Dissolved chromium was detected in two wells, B5 and G3, located outside the Black Liquid area but along its eastern edge (see Figure 4-52). Dissolved chromium was not detected at wells MW-12, H10, and B6 even though they are located within the Black Liquid area. Chromium was detected, however, in unfiltered groundwater samples collected from these three wells.

It should be noted that dissolved chromium concentrations, even within the Black Liquid area, are lower than the action level (100  $\mu\text{g/l}$ ) in all but three cases. The monitoring wells that indicated dissolved chromium concentrations higher than the action level during Round 1 were DM-2A (149  $\mu\text{g/l}$ ), DM-8 (153  $\mu\text{g/l}$ ), and DM-5 (365  $\mu\text{g/l}$ ).

The action level (i.e., the MCL) of 100  $\mu\text{g/l}$  is for total chromium, in both trivalent and hexavalent forms. U.S. EPA's rationale for including both the chemically reduced (trivalent) and oxidized (hexavalent) forms was that trivalent chromium might become oxidized to the hexavalent form when the water is treated with an oxidizing biocide, such as chlorine, prior to its distribution for potable uses. Groundwater beneath the RPI Facility has several characteristics of a chemically reducing environment (discussed in Section 4.3.7) so the chromium is probably trivalent, and conditions strongly mitigate against conversion to the hexavalent form.

Normally, any dissolved chromium found in groundwater would occur in the more toxic hexavalent state (chromate or dichromate), rather than in the less toxic trivalent state. When present, hexavalent chromium is nearly always of anthropogenic origin. This makes

the occurrence of dissolved chromium beneath the RPI Facility worthy of further comment. The most common method for distinguishing between these two oxidation states is with the "diphenyl carbazide" colorimetric test (SW-846 Method 7196A). However, highly colored water or the presence of elevated concentrations of certain metals, including iron, can give "false positive" results for hexavalent chromium. Groundwater beneath the RPI Facility is colored in some areas and contains iron and manganese; therefore, efforts to directly verify that the chromium is in the trivalent form using the diphenyl carbazide method have not been made. Instead, indirect methods of inferring the oxidation state of chromium at the Facility have been used.

Groundwater from a number of locations was sampled and analyzed for dissolved chromium and for other constituents that can provide strong indications for the presence or absence of hexavalent chromium during Round 1. The other constituents that served as indicators of the oxidation state of chromium are divalent iron (dissolved), divalent manganese (dissolved), and total organic carbon. Detection of any of these constituents in groundwater, especially at elevated concentrations, suggests chemically reducing conditions that are inconsistent with the existence of hexavalent chromium. In fact, the presence of dissolved iron in the ferrous (divalent) state would rule out the potential for chromium to exist in the hexavalent state. The results of Round 1 testing (Table 4-22) were used to guide any additional testing during Round 2.

Samples analyzed for dissolved chromium were discolored because of the presence of spent sulfite liquor (lignin—see Section 4.3.8). Direct analysis for hexavalent chromium with the diphenyl carbazide method would be difficult because of the elevated dissolved iron and groundwater discoloration. Consequently, in Round 2, dissolved oxygen measurements of groundwater within selected wells (Table 4-23) were relied upon to support chemically reducing (low-oxygen) conditions in groundwater, as noted above. The dissolved oxygen concentrations in the wells that were sampled ranged from 0.1 to 1.4 mg/l, whereas the oxygen concentration in water that was saturated with air at the temperatures reported in Table 4-23 would fall between approximately 9.5 and 10.5 mg/l. The combination of elevated iron and manganese, low dissolved-oxygen values, and elevated TOC strongly support a chemically reducing environment in which chromium could not exist in the hexavalent state.

#### **4.3.7 Conventional Water Quality and Biological Indicator Parameters**

Selected groundwater samples collected during the RFI were analyzed for conventional water quality and biological activity indicators. These analyses were performed to characterize the general groundwater chemistry and evaluate conditions relating to current or potential biological degradation (biodegradation) of organic contaminants in groundwater.

The general water quality parameters included the following:

- Alkalinity
- Hydroxide alkalinity
- Bicarbonate
- Calcium (for hardness)
- Carbonate
- Chloride
- Magnesium
- pH
- Specific conductance
- Temperature
- Total dissolved solids
- Total organic carbon

With the exception of temperature and specific conductance, all the above data were collected during Round 1. Temperature and specific conductance data were collected during both Rounds 1 and 2.

Biological activity indicators included the following:

- Dissolved oxygen (Round 2 only)
- Kjeldahl nitrogen
- Nitrate
- Nitrite
- Orthophosphate
- Phosphorus
- Sulfate
- Sulfide

With the exception of dissolved oxygen (DO), all the above data were collected during Round 1. DO measurements were collected during Round 2 only.

The conventional water quality and biological indicator data collected at the Facility were used to:

- Assess whether biological degradation is taking place at the Facility, and the types of reactions that may be occurring.
- Identify and evaluate conditions that may limit or control biodegradation rates (e.g., the supply of nutrients and other reactants).
- Aid in selecting input parameters to be used in fate and transport analyses (see Section 4.8).



- Provide preliminary information for assessing corrective measure alternatives during the Corrective Measures Study.

The results of the conventional water quality parameter analyses are presented in Table 4-24. Table 4-25 provides the biological indicator results.

The data in Table 4-25 indicate that subsurface conditions are chemically reducing (i.e., have low redox potential). DO concentrations measured *in situ* (in the screened portion of each well) are consistently low (less than 1.5 mg/l), even in groundwater that is upgradient (east) of the toluene plume. Concentrations of other parameters also indicate reducing conditions; for example, nitrate and sulfate concentrations are also low. As presented in Section 4.3.6, both iron and manganese are present in groundwater in their dissolved forms. The soluble, chemically reduced forms of these metals indicate a reducing environment. The redox conditions are addressed further in Section 4.3.6.

Biodegradation of organic contaminants is the result of biochemical reactions that are mediated by microorganisms. The organisms metabolize the contaminants to obtain energy and cell "building blocks." As such, there is an order of preference in the type of degradation activity that will take place in the subsurface, depending on the energy released by the biochemical reactions. The order of preference is:

- Aerobic degradation, using oxygen
- Anaerobic degradation by reduction of nitrate
- Anaerobic degradation by reduction of sulfate
- Anaerobic degradation by methanogenesis

Oxygen is the most efficient reactant, with the result that most contaminants are readily degraded under aerobic conditions. However, oxygen flux into an aquifer is typically limited. In most cases, available oxygen is depleted by aerobic biodegradation of organic species faster than it is replenished. Thus, oxygen is typically the limiting factor in aerobic biodegradation. The low DO concentrations in groundwater at the RPI Facility suggest that little oxygen is available for aerobic activity, even in groundwater upgradient of the toluene plume and in Area BG. Because DO is low across the Facility, aerobic degradation of toluene does not currently appear to be a significant process.

The order of preference listed above for biodegradation processes corresponds to redox conditions. As the more oxidized species are depleted, conditions become more reducing. In a low-oxygen environment, such as that indicated by the water quality data in Tables 4-24 and 4-25, contaminants may undergo anaerobic degradation by organisms that reduce nitrate or sulfate, or by methanogens (methane-producers) in the most highly reduced environments. An assessment of which anaerobic processes may be occurring includes examining the data for spacial trends in either the reactants or the products of each reaction; consulting literature for documented cases of degradation of a specific contaminant via each process; and considering redox potential.

For example, if nitrate or sulfate reduction were occurring at the RPI Facility, the nitrate or sulfate concentrations should be higher in wells upgradient (east) of the toluene plume, and lower within and downgradient (west) from the area of highest contamination. The groundwater data do not show this trend for either of these reactants. Concentrations of nitrate and nitrite are uniformly low; therefore, there is no evidence of biodegradation via nitrate reduction. Concentrations of sulfate are highly variable and the data are inconclusive. Groundwater with higher levels of sulfate (around 50 mg/l and higher) may support degradation via sulfate reduction, while sulfate reduction is unlikely for sulfate levels below around 10 mg/l. (The presence of sulfide is an indicator of low redox potential; however, its use as an indicator of sulfate reduction activity is limited since sulfide levels are probably controlled by the precipitation of ferrous iron.) The data in Tables 4-24 and 4-25 do not provide direct evidence of degradation via sulfate reduction, but the potential exists for toluene degradation through this process.

Under highly reducing conditions such as those indicated by groundwater data for the RPI Facility, anaerobic degradation may occur via a process called methanogenesis. During methanogenesis, the organic contaminant is broken down into carbon dioxide (or acetate) and methane. Methane is the most effective monitoring parameter for assessing the presence and extent of methanogenesis, since it is a by-product of the reaction. Because of the expectation of aerobic conditions in shallow groundwater, samples collected during the RFI were not analyzed for methane. However, health and safety-related air monitoring measurements conducted at monitoring well well-heads during the RFI fieldwork suggest that methane might be present. These air quality measurements were often conducted using both a combustible gas indicator (CGI) and a PID. The CGI will respond to all explosive organic vapors (at detectable concentrations), including methane. In contrast, the PID only detects organics with certain ionization potentials; methane is not among these and therefore is not detected by a PID. Comparison of CGI and PID data collected at open well-heads for wells B4 and DM-5 suggests the presence of methane in the well casing.

The groundwater quality data alone do not indicate conclusively that toluene biodegradation is occurring by anaerobic degradation. However, the steep concentration gradient around the perimeter of the toluene plume (Figures 4-47 and 4-48) suggests that biodegradation is occurring. Toluene has been shown to be readily degraded anaerobically by both sulfate reduction and methanogenesis under laboratory and field conditions at other sites. Past studies indicate that the rate of anaerobic degradation of toluene by methanogenesis can be competitive with that of aerobic degradation of toluene, with the highest rates achieved by methanogenesis. The data collected to date suggest that biodegradation may be occurring via methanogenesis, and possibly sulfate reduction. Measurements of methane in groundwater and soil gas will be conducted as part of a CMS if natural or enhanced biodegradation corrective measures are considered.

Other data presented in Tables 4-24 and 4-25 provide useful information regarding the parameters affecting the potential for biodegradation to occur at the Facility. Concentrations of nitrogen and phosphorus are sufficiently high that these nutrients are probably not limiting reaction rates. The pH and temperature are in the acceptable range for most

biodegradation processes. Depending on the type of biological processes under consideration, alkalinity data may be used to calculate buffering capacity for pH changes that can occur as a result of biological processes that affect redox potential.

#### 4.3.8 Extent of Black Liquid

As discussed in the RFI Workplan, part of the Facility is underlain by groundwater that is dark brown to black in color. The groundwater is not oily or viscous, but resembles water that is rich in tannic acid. Conventional groundwater chemistry data suggest this dark-colored groundwater is high in TOC and bicarbonate compared to groundwater in other areas of the Facility (the high bicarbonate concentration is evidenced by effervescence when groundwater is poured into acidified sample bottles). For convenience, this dark-colored groundwater has been termed "Black Liquid."

The RFI objectives for groundwater quality included 1) investigating the presence and extent of the Black Liquid in the Upper Aquifer, and 2) evaluating whether toxic or regulated substances are co-distributed with the liquid. The estimated extent of the liquid was evaluated during the RFI by visually inspecting monitoring-well purge water generated during the Round 1 groundwater sampling effort (conducted in January and February 1994). The chemical characteristics of the liquid and an assessment of the presence or absence of toxic substances was accomplished by sampling groundwater monitoring wells during Rounds 1 and 2.

Figure 4-52 shows the estimated areal extent of the Black Liquid at the Facility. The configuration of the liquid area is similar to that identified in July 1994 (see Figure 4-19 in the RFI Workplan), indicating that the location and configuration of the liquid did not change significantly in 6 months. The source of the liquid is believed to be the spent sulfite liquor (lignin) that was stored and used onsite. The source of the chromium in the liquid may be chromic acid that was reportedly used by the lignin supplier to clean its storage vessels.

A comparison of groundwater data indicates that there is a correlation between the presence of the Black Liquid and the presence of chromium (see Section 4.3.6). However, no other toxic substances are known to be specifically associated with the liquid based on a review of the available data. With the exception of three results for monitoring wells DM-2A, DM-8, and DM-5 (149  $\mu\text{g/l}$ , 153  $\mu\text{g/l}$ , and 365  $\mu\text{g/l}$ , respectively), dissolved chromium concentrations in the Black Liquid area do not exceed the action level of 100  $\mu\text{g/l}$ .

#### 4.3.9 Groundwater Investigation Summary

Groundwater quality at the Facility was assessed during the RFI in several ways. Round 1 of the investigation included collection and analysis of samples from all 30 pre-RFI monitoring wells (Figure 2-3). A HydroPunch investigation was also conducted during Round 1 in Areas A2, A4, A5, and A6 (Figure 2-19) to assess the magnitude and extent of the toluene plume. During Round 2, 19 monitoring wells were sampled including eight

new wells installed in the vicinity of the toluene plume (Figure 2-20). Monitoring to assess the presence and extent of LNAPL was also conducted during the HydroPunch investigation and on a monthly basis at monitoring wells.

The groundwater quality results were compared to action levels (federal MCLs for drinking water). The results indicate that toluene in groundwater beneath the Tank Farm area (Figures 4-47 and 4-48) is the primary constituent of concern at the Facility. Toluene was found to exceed the 1,000  $\mu\text{g/l}$  action level at 10 Facility monitoring wells (wells H1, H10, H11, MW-12, MW-14, MW-15, MW-16, MW-17, MW-18, and MW-19). The area where toluene exceeds the 1,000  $\mu\text{g/l}$  action level is approximately 1.5 acres. Concentrations in the upper 10 feet of the Upper Aquifer range up to several hundred thousand micrograms per liter and decrease significantly with depth. Toluene concentrations in the lower half of the Upper Aquifer are two to three orders of magnitude lower than those in the upper 10 feet of the aquifer (Figures 4-49 and 4-50). RFI groundwater monitoring data indicate that the toluene plume has not migrated offsite, either to adjacent properties or to surface water bodies.

Several other organic compounds are present within the boundaries of the toluene plume at concentrations exceeding action levels. These compounds are of secondary concern because they are less widespread and generally do not exceed their respective action levels to the same degree as toluene.

Three organic compounds were detected in the Lower Aquifer. Bis(2-ethylhexyl)phthalate, acetone, and toluene were detected in Lower Aquifer wells DM-1B, DM-3B, and B1B at relatively low concentrations. None was detected above its respective action level. Given the hydrogeologic conditions at the Facility, it is unlikely that these organic compounds migrated from Upper Aquifer to the Lower Aquifer. It is possible that constituents entered the Lower Aquifer via surface water infiltrating the flush-mounted wellheads for these wells. It is also possible that the source of the bis(2-ethylhexyl)phthalate is the PVC monitoring well construction materials, as this compound is a common plastizer in PVC and was also detected at low concentrations in 11 Upper Aquifer wells.

Benzo(a)pyrene, a PAH compound, is the only organic compound detected above an action level outside the toluene plume area. Benzo(a)pyrene (with an action level of 0.2  $\mu\text{g/l}$ ) was detected at monitoring wells DM-2A, DM-5, and G3 at concentrations of 1, 6, and 2  $\mu\text{g/l}$ , respectively (all data are J-qualified). PAHs were never used at the Facility. Further, they are known to be widely distributed in soil and groundwater across the Facility and vicinity, as discussed in Appendix J. Therefore, PAHs are not considered constituents of concern for the Facility and are not recommended for inclusion in the CMS.

Only three metals (arsenic, beryllium, and chromium) were detected in filtered samples at concentrations exceeding action levels. Of these, arsenic and beryllium are not known to have been used at the Facility. Further, arsenic is known to be present regionally at elevated concentrations (see Appendix J). Therefore, these two metals are not considered constituents of concern. Chromium was detected above its action level (100  $\mu\text{g/l}$ ) in three

Upper Aquifer monitoring wells (DM-2A, DM-5, and DM-8 at 149, 365, and 153  $\mu\text{g/l}$ , respectively). Groundwater chemistry data for the Upper Aquifer indicate that chromium is present in the trivalent form and not the more toxic hexavalent form presumed by the action level. Therefore, chromium is also not considered a constituent of concern for the Facility. Chromium, arsenic, and beryllium are not recommended for inclusion in the CMS.

LNAPL is not present in beneath the Facility in significant or recoverable volumes based on the findings of the Hydropunch investigation and monthly LNAPL monitoring being conducted as an Interim Measure. Chemical characterization of the LNAPL conducted prior to the RFI indicates that it is composed primarily of non-toxic food-grade mineral oil (Penetec oil). LNAPL is not recommended for evaluation during the CMS. If a recoverable volume of LNAPL is noted in a Facility monitoring well in the future, it will be removed from the well as an Interim Measure.

In summary, the toluene plume warrants inclusion in the forthcoming CMS. Other constituents present in the toluene plume at concentrations above their respective action levels will be addressed in conjunction with the evaluation of toluene. Although there are several organic compounds detected outside the toluene plume above action levels, none of these are recommended for inclusion in the CMS for the reasons stated above and earlier in Section 4.3.

There are a number of constituents detected in groundwater at the Facility that do not have an action level (an MCL). In most cases, these will be addressed in the forthcoming Risk Assessment and Media Cleanup Standards evaluation. If a RFI groundwater result for such a constituent exceeds its final Media Cleanup Standard, the constituent will be carried forward and addressed in the CMS. Inorganic and general water quality constituents present naturally in groundwater or that act as indicator parameters will not be evaluated during the Risk Assessment and Media Cleanup Standards evaluation. These are:

Conventional Water Quality Parameters

Alkalinity  
Bicarbonate  
Carbonate  
Kjeldahl nitrogen  
Orthophosphate  
Phosphorus  
Sulfate  
Sulfide  
Total organic carbon  
Total dissolved solids

Inorganics

Aluminum  
Calcium  
Magnesium  
Potassium  
Sodium

The following parameters were detected at the Facility, do not have action levels, and will be analyzed during the Risk Assessment and Media Cleanup Standards evaluation:

Inorganics

Cobalt  
Vanadium

Pesticides/PCBs

bhc-gamma (lindane)  
Endosulfan I  
Endosulfan Sulfate

Semivolatiles

Acenaphthene  
Bis(2-chloroethyl)ether  
Bis(2-ethylhexyl)phthalate  
Chrysene  
Dibenzofuran  
2,4-dimethylphenol  
Fluoranthene  
Fluorene  
2-methylnaphthalene  
2-methylphenol  
4-methylphenol  
Naphthalene  
Phenol  
Pyrene  
Vanillin

#### 4.4 Sediment Investigation

The RFI sediment investigation was conducted using a nonparametric sampling approach, as described in the RFI Workplan. As described in Section 2.5, sediment sampling was conducted during two low-tide events (one each during Round 1 and Round 2 of the RFI) in the offshore investigation Area A11 along the western portion of the Facility.

The samples collected during Round 1 and Round 2 were analyzed for inorganics (metals), semivolatiles (including PAHs), pesticides, PCBs, TOC, and other conventional parameters, and physical parameters including grain size and specific gravity, as summarized in Table 2-13. A minimum of seven, and maximum of 14, samples were analyzed depending on the constituent group. Figure 4-53 shows the sampling locations and a tabular statistical summary of the analytical results.

The Department of Ecology has applied the Washington State Marine Sediment Management Standards for Puget Sound (WAC 173-204) to the Duwamish Waterway sediments, including this section of the Waterway adjacent to the RPI Facility (personal communication with Dr. Teresa Michelsen, Washington State Department of Ecology, October 27, 1994). Sluggish flow in the Duwamish Waterway and strong tidal forces allow a saltwater wedge to intrude into the Duwamish Waterway upstream of the Facility. Table 4-26 compares the chemical parameter results from Round 1 and Round 2 to the

Marine Sediment Management Standards, including the Sediment Quality Standards (SQSs; WAC 173-204-320, Table I) and the Minimum Cleanup Levels (MCULs; WAC 173-204-520, Table III). The SQS sediment criteria are screening levels that correspond to chemical concentrations that result in no adverse effects on biological resources or significant health risk to humans. The marine sediment MCUL chemical criteria are also the Puget Sound Marine Sediment Cleanup Screening levels; these MCULs are considered the action levels for the RFI.

#### 4.4.1 Sediment Investigation Results

The results of both the Round 1 and Round 2 sampling events for the RFI sediment investigation are summarized in the following sections. As discussed in Section 2.5, TOC analyses were performed on samples collected during Round 2 only. The TOC results from Round 2 have been used to normalize dry-weight station sample results for non-polar organic compounds (e.g., PAHs and PCBs) from Round 1 and Round 2 to allow comparison to the Marine Sediment Management Standards (Table 4-26). To calculate TOC-normalized concentrations, the dry-weight concentrations are divided by the decimal fraction representing the percent organic carbon in the sediment. The TOC-normalized results are discussed in the following sections, as applicable. Note that Table 4-26 shows both detected and nondetected results, unlike data tables presented previously for soil and groundwater. The nondetected results are presented so that detection limits can be compared to the Marine Sediment Management Standards.

##### *Inorganic Compounds (Metals)*

A total of 19 metals were detected during Round 1 sampling (Figure 4-53). Metals concentrations in the sediments did not exceed the Marine Sediment Management Standards (Table 4-26). The following metals listed with their concentration ranges were detected in all samples:

- Arsenic (2.8 mg/kg to 9.9 mg/kg)
- Chromium (12.5 mg/kg to 25 mg/kg)
- Copper (13.2 mg/kg to 57.4 mg/kg)
- Lead (5.2 mg/kg to 26 mg/kg)
- Zinc (32.4 mg/kg to 92.5 mg/kg)

One sample, collected at sampling station 5, was analyzed for metals during Round 2. As shown in Table 4-26, the results were comparable to the Round 1 results for station 5.

##### *Semivolatile Organic Compounds*

Twenty-one semivolatiles, including PAHs, were detected in 14 sediment samples collected during Rounds 1 and 2. Figure 4-53 summarizes the frequency of detection and detected concentration ranges for these parameters. The following semivolatiles, listed with their concentration ranges in parentheses, were detected in all samples:

- Fluoranthene (42  $\mu\text{g/kg}$  to 1,200  $\mu\text{g/kg}$ )
- Pyrene (37  $\mu\text{g/kg}$  to 890  $\mu\text{g/kg}$ )
- Bis(2-ethylhexyl)phthalate (29  $\mu\text{g/kg}$  to 710  $\mu\text{g/kg}$ )

The most frequently detected semivolatile organic compounds in the sediment samples were PAHs. Although PAHs were never used at the RPI Facility for processing or manufacturing, the presence of PAHs is expected because of their widespread distribution reported for the Duwamish Waterway and Elliott Bay (e.g., *Elliott Bay Waterfront Decontamination Study, Literature Search*, Washington State Department of Ecology, 1993). A summary of PAH occurrences in sediments and other media in the vicinity of the RPI Facility is included in Appendix J.

The Marine Sediment Management Standards for PAHs and other non-polar semivolatile organic compounds are expressed in terms of mg/kg-organic carbon (Table 4-26). In accordance with the standards, if chemical analysis identifies an undetected value for one or more compounds, the detection limit is reported as the result based on TOC. The TOC-normalized concentrations are calculated as described above.

No exceedances of the Marine Sediment Management Standards occurred for samples where PAHs or other non-polar semivolatile organic compounds were detected. However, TOC-normalized non-detected values from Round 1 results (i.e., the method detection limits) exceeded SQS criteria and, in some cases, MCULs. The analytical laboratory achieved lower detection limits for analyses performed on the Round 2 samples. The Round 2 TOC-based detection limits did not exceed the Sediment Management Standards with the exception of SQS criteria for hexachlorobenzene (the SQS is 0.38 parts per million [ppm] TOC) and 1,2,4-trichlorobenzene (the SQS is 0.81 ppm TOC).

Sediment criteria for polar organic compounds, such as phenols, are expressed in dry weight. No exceedances of the Marine Sediment Management Standards for these compounds occurred for samples with detectable concentrations. The analytical results for Round 1 had method detection limits elevated above the Marine Sediment Management Standards for some polar organic compounds. The Round 2 analyses achieved lower detection limits and confirmed that polar organic compounds were not present at concentrations at or above the Marine Sediment Management Standards.

### *Pesticides*

Pesticides were analyzed during both rounds of the sediment investigation. Figure 4-53 summarizes the frequency of detection and detected concentration ranges for pesticides. The most frequently detected pesticides in the samples, listed with their concentration ranges in parentheses, were:

- Gamma-chlordane, detected in 13 samples (0.88  $\mu\text{g/kg}$  to 4.4  $\mu\text{g/kg}$ )
- 4,4'-DDD, detected in 11 samples (4.3  $\mu\text{g/kg}$  to 160  $\mu\text{g/kg}$ )



- 4,4'-DDE, detected in 9 samples (2  $\mu\text{g/kg}$  to 45  $\mu\text{g/kg}$ )
- 4,4'-DDT, detected in 10 samples (3.2  $\mu\text{g/kg}$  to 180  $\mu\text{g/kg}$ )

Pesticides were not detected in all samples. Regulatory criteria have not been established for pesticides in sediments. For comparison purposes, these concentrations do not exceed MTCA Method C or Method B cleanup levels for pesticides in soil.

### ***PCBs***

The Marine Sediment Management Standards are expressed in terms of total PCBs normalized to TOC (Table 4-26). Total PCBs represents the sum of individual isomers where, if a chemical analysis identifies an undetected value for one or more individual isomers, the detection limit is used to calculate the sum. The TOC-normalized values are calculated as described earlier for the non-polar organic compounds.

Two PCB isomers were detected in the sediment samples collected during Round 1 and Round 2 (Figure 4-53). The PCBs detected, listed with their concentration ranges in parentheses were:

- Aroclor-1254, detected in 7 samples (24  $\mu\text{g/kg}$  to 210  $\mu\text{g/kg}$ )
- Aroclor-1260, detected in 3 samples (29  $\mu\text{g/kg}$  to 50  $\mu\text{g/kg}$ )

PCBs were not in all samples.

TOC-normalized PCB totals calculated from Round 1 data exceeded the marine SQS (12 ppm-TOC) at all sediment sampling stations. TOC-normalized PCB totals calculated from Round 2 data where lower method detection limits were achieved, exceeded the marine SQS at sampling station 4 only. The exceedance observed at station 4 was for Aroclor 1254 at 210  $\mu\text{g/kg}$ ; no other PCB isomers were detected in the sample. The marine sediment MCUL (65 ppm-TOC) was not exceeded at any station.

PCBs are widespread contaminants in Duwamish Waterway and Elliott Bay sediments (e.g., *Elliott Bay Waterfront Decontamination Study, Literature Search*, Washington State Department of Ecology, 1993). Many potential sources of PCBs (present and historical) in the area include combined sewer overflow (CSO) outfalls in the vicinity, such as the Norfolk Street CSO that discharges approximately 1/2 mile upstream of the Facility, and former industrial facilities and practices in the Duwamish Corridor.

### ***Conventional Parameters***

Sediment samples collected during Round 2 were analyzed for ammonia, sulfide (as S), TOC, pH, preserved total solids, and total volatile solids. The conventional parameter results were as follows:

- Ammonia concentrations ranged from 1.62 mg/kg to 15.3 mg/kg

- Sulfide concentrations ranged from <2.73 mg/kg to 136 mg/kg
- TOC ranged from 1.78 percent to 2.61 percent
- pH values for sediments ranged from 6.96 to 7.86
- Preserved total solids ranged from 51.02 percent to 76.47 percent
- Total volatile solids ranged from 12,100 mg/kg to 32,900 mg/kg

The conventional parameter results are within expected concentration ranges for natural marine/alluvial sediment deposits. No regulatory criteria exist for these parameters.

### *Physical Parameters*

The results of grain size, percent solids, and specific gravity testing performed during Round 2 are summarized in Table 4-27. The data confirm field observations that the shoreline sediments grade from predominantly medium sands in the south, near Slip No. 6, to fine sands and sandy silts to the north.

#### **4.4.2 Sediment Investigation Summary**

In summary, the RFI sediment investigation results do not indicate chemical parameter concentrations detected at or above the marine sediment MCULs, which are considered the action levels for the RFI.

PCB totals calculated for the Round 2 data indicated one exceedance of the marine SQS. One station with an exceedance of the marine SQS is not sufficient to define "a station cluster of potential concern" (WAC 173-204-510); such a station cluster would be defined if the average contaminant concentration for any three stations (with the highest concentrations for any particular contaminant) exceeded the cleanup screening levels (marine sediment MCULs) (WAC 173-204-520).

The PCB totals calculated for the Round 1 data, which had higher method detection limits, are considered to be superseded by the Round 2 data results. The Round 2 results achieved lower detection limits and are therefore considered more representative of sediment quality at the RPI Facility. Further, PCBs are known to be widespread in the sediments of the Duwamish Waterway and Elliott Bay, with likely sources including discharge from CSOs and historical industrial practices in the region. The PCBs detected are believed to be associated with this regional condition, and not with the RPI Facility.

### **4.5 Ecological Site Assessment**

As described in Section 2.6, an ecological site assessment was conducted at the Facility to qualitatively identify plants and animals onsite and assess possible effects on them from hazardous constituents currently under investigation. The site assessment was performed on August 18, 1994, during a low (minus-1-foot) tide, which exposed much of the

intertidal mud flats of the shoreline area. Weather conditions were typical for August: sunny, hot, and dry, providing a good opportunity to observe the Facility.

#### 4.5.1 Facility Observations

The upland area of the site has been extensively developed, with large portions covered by gravel for blacktop, or by cement. Several structures have been removed, leaving cement slab foundations and short foundation walls. Intact buildings near the entrance to the Facility are landscaped with domestic shrubs and small trees.

Cover for birds and small mammals is primarily provided by common invasive species such as blackberries, common tansy, and Scotch broom found at the edges of the site. A mature big-leaf maple was found growing at the southeastern boundary. Birds observed in the upland portions of the site include California quail, killdeer, starlings, song sparrows, robins, and crows. While not seen during this assessment, rabbits have also reportedly been observed on the site. Overall, wildlife habitat value on this portion of the site is limited because of structural development and site disturbance.

The shoreline area, which is less affected by site development, supports healthier vegetative growth on the riverbank, which in turn provides resting and feeding areas for wildlife. The shoreline area starts with a steep bank of medium to large boulders, and drops approximately 15 to 20 feet in elevation to the high water mark of the Duwamish Waterway. Vegetation on the bank is fairly dense and lush and includes blackberry, common tansy, flat peavine, pepperwort, douglas aster, and velvet grass.

Below the waterline, the property extends an additional 150 feet into the river channel over an area of intertidal sediments. Algal mats were observed covering the northern third of the exposed sediments during the low tide. This area also contains the remains of a pier, several pilings, and a log boom. Common shore birds observed in this area include Thayer's, ring-billed, and Bonaparte's gulls; belted kingfishers; cormorants; Barrow's and common goldeneyes; and mallards. Migrating and over-wintering birds observed in the shoreline area during the late winter include goldeneyes, mergansers, and grebes. Great blue herons have also been observed flying over the site. While not seen during this assessment, river otters and nesting Canada geese have also been observed on the shoreline and the riverbank, respectively.

The Duwamish River is a migration route for salmonids (including coho, chinook, and chum salmon), as either smolts or mature returning salmon. The adult residence time in the river along the shoreline area is limited, minimizing the opportunity for exposure from any Facility releases. Juveniles do spend more time in the lower reaches of the river, which includes the Facility shoreline.

In general, wildlife species observed during the site assessment and other RFI activities do not appear to be stressed or adversely affected by the operations of the Facility or constituents historically used there. No known species designated as threatened or endangered

by federal or state agencies have been observed on the site in either the upland or shoreline areas.

#### **4.5.2 Site Assessment Summary**

The Facility is characterized by a variety of plants and animals that do not appear potentially affected by the constituents of concern that were investigated in the RFI. Wildlife species do not appear to be stressed or adversely affected by the operations of the Facility or constituents historically used there. No known species designated as threatened or endangered by federal or state agencies have been observed on the site. The upland area of the Facility has limited wildlife habitat value because of past structural development and disturbance, but the shoreline area supports healthier vegetative growth that provides resting and feeding areas for wildlife.

### **4.6 Seep Assessment**

As described in the RFI Workplan, seep sampling was planned for the RFI to assess the quality of groundwater discharging to the Duwamish Waterway and evaluate the potential for cross-media contamination from groundwater to surface water and sediments. Several inspections were made of the riprap and intertidal zone along the Duwamish Waterway during the Round 1 investigation in an attempt to identify seeps that could be sampled. No seeps were observed until the Round 2 investigation. During the Round 2 sediment sampling conducted during a minus-1-foot tide on August 18, 1994, a small seep was observed along the base of the rip-rap bank at the southwest corner of the Facility. At that time, however, seep sampling was deferred for the reasons outlined in Section 2.7.

At present, sampling of the seep is planned for a minus-tide event that will occur during daylight hours on March 20, 1995. The seep sample will be analyzed for selected inorganics (metals and ions), volatile organic compounds, semivolatile organic compounds, and formaldehyde, as described in the RFI Workplan. The results of the seep sampling and analysis will be presented in an addendum to this RFI Report.

### **4.7 Air Emissions Investigation**

As described in Section 2.8, air samples were collected on August 11, 1994, in Area A4 and in Area A8 at the west end of the old Maintenance Shop (the sampling locations are shown in Figure 2-22). The purpose of the air emissions investigation was to assess the potential release of volatile emissions from the soils and the potential impacts of such releases.

Table 4-28 shows the air sampling results in concentration and flux emission rates along with Acceptable Source Impact Levels (ASILs) and Threshold Limit Values (TLVs). (TLVs are values established by the American Conference of Governmental Industrial

Hygienists [ACGIH] for workplace exposures. ASILs are guidelines established by the state Department of Ecology to evaluate the effects of new sources of air toxics in ambient air.)

The organic vapor monitor (OVM) was calibrated with a 100 parts per million by volume (ppmv) isobutylene standard using a 10.6-electronVolt lamp and a response factor of 1.0. The concentration values listed in Table 4-28 are those observed in the samples from the flux chamber. Therefore, these results are diluted with 5 liters per minute sweep air in the approximate flux chamber volume of 0.032 m<sup>3</sup>. The flux rates have been calculated using the chamber area of 0.13 m<sup>2</sup> and sweep air flow rate of 5 liters per minute.

Acetone, benzene, and toluene were all detected (Table 4-28). The concentrations observed in these samples were generally low, being at or near the method detection limits. The results were also near the equipment blank values and, in the case of toluene, below the equipment blank values. Acetone and toluene were detected in the two field samples and in the equipment blank. The results ranged from 6.9 to 9.3 ppbv for acetone and 1.2 to 11.5 ppbv for toluene. Benzene was detected in the sample from Area A4 only (sample A04-AM-01), at a concentration of 3.6 ppbv. As with acetone and toluene, this result is only slightly higher than the equipment blank result (<1.0 ppbv).

There are no defined action levels for air. However, the sample concentrations from the flux chamber were below the TLVs for all parameters and below the ASILs for all parameters except methylene chloride and benzene. The method detection limits are not sufficiently sensitive to show concentrations below the ASILs for these two compounds.

#### 4.8 Fate and Transport of Constituents in Groundwater

Fate and transport analyses were conducted for selected constituents of concern detected in groundwater at the Facility. The initial two analyses consisted of calculations of constituent migration rates and predictions of constituent concentrations in the Upper Aquifer at the boundary with the Duwamish Waterway. Predictions of toluene concentrations in the Upper Aquifer were then made using Bioplume II modeling.

##### 4.8.1 Migration Rates of Constituents in Groundwater

An evaluation of potential constituent migration in groundwater was conducted for two volatile organic compounds, two semivolatile organic compounds, and two inorganic compounds (metals). These constituents were selected because they are known to be associated with the Facility and are among the most mobile constituents detected there. They are listed by chemical category in Table 4-29.

## *Approach*

The estimate of the migration rate of each of the constituents listed in Table 4-29 is based on two physical processes: the rate at which groundwater moves in the subsurface, and the tendency for the constituent to sorb to soil particles in the aquifer. Constituents that do not naturally sorb to solids in the aquifer will move at a rate comparable to that of the prevailing groundwater flow velocity. Constituents that do sorb to the aquifer solids are "retarded" in their movement, and migrate at a rate that is slower than the effective groundwater velocity.

The groundwater flow velocity was estimated for the Upper Aquifer at the Facility. Estimates of velocity are based on hydrogeologic parameters measured at a site, including hydraulic conductivity, porosity, and the hydraulic gradient over the site. An average hydraulic gradient of 0.002 ft/ft was used, based on the 27-day continuous groundwater elevation monitoring program conducted from January 19 through February 15, 1994. As discussed in Section 4.1.2, the data collected during periods when groundwater extraction was occurring at Kenworth's site indicate that the net groundwater flow in the western portion of the Facility does not flow to the Duwamish Waterway or to Slip No. 6 as expected; instead, groundwater flow in the Upper Aquifer appears to be converging from the east, west, and south, and flowing north toward the Kenworth site. Under normal conditions, groundwater in the Upper Aquifer likely flows toward the Duwamish Waterway and Slip No. 6. Therefore, in order to evaluate the potential constituent migration under normal conditions (i.e., in the absence of pumping by Kenworth), the average net gradient from the eastern portion of the Facility was applied to the model (0.002 ft/ft). Appendix K contains the equation and the input parameters used to calculate the groundwater velocity.

Typically, organic compounds exhibit the tendency to sorb to soil particles. This sorption effectively slows the rate of migration of a constituent relative to the rate of groundwater flow. A retardation factor is often used to denote the velocity of a constituent in groundwater relative to the actual groundwater velocity. In this case, the retardation factor was calculated from a constituent's organic carbon partition coefficient (a measure of its tendency to sorb to the soil matrix), and from the bulk density, porosity, and fraction of organic carbon in the soil matrix of the Upper Aquifer. (This is described in more detail in Appendix K.)

Although inorganic metals may also be retarded in their movement in groundwater, the sorption of metals is quite complex. It is a function of the speciation of the metal and is dependent on soil conditions such as pH and redox potential. This information and these relationships have not been quantified for the Facility; therefore, for the purposes of this analysis it was conservatively assumed that chromium and copper move at the same velocity as groundwater (i.e., they are not retarded).

Details of the estimates of constituent-specific retardation factors and migration rates, along with associated equations, are provided in Appendix K.

## Results

Table 4-30 presents the results of the migration rate analysis. The table shows the following for each of the six chemicals considered:

- Organic carbon partition coefficient (ml/g)
- Chemical-specific sorption coefficient (ml/g)
- Retardation factor (unitless)
- Groundwater velocity (ft/day)
- Contaminant velocity (ft/day)

The most mobile of the organic compounds listed in Table 4-30 is acetone (migrating at a rate of 10 feet per year), followed by toluene and 2-methylphenol (8 feet per year). Pentachlorophenol is more highly sorbed, and hence moves at a relatively slower rate in the Upper Aquifer (3 feet per year). The average groundwater flow velocity at the Facility is 11 feet per year; the migration rate for pentachlorophenol, the most highly sorbed contaminant, is approximately 25 percent of the rate of groundwater flow.

It should be noted that tidal influences on groundwater flow rates and directions at the Facility are significant, especially at the western edge of the Facility (see Section 4.1.2). The calculated migration rates are considered conservative because constituents present in groundwater in the western portion of the Facility do not migrate directly to the Duwamish Waterway; instead, on their path to the Waterway they oscillate back and forth under the influence of tidal action.

### 4.8.2 Estimates of Constituent Concentrations in Groundwater

A major objective of these fate and transport analyses was to assess potential impacts to the Duwamish Waterway, the nearest potential environmental receptor. This was accomplished by estimating constituent "exit" concentrations in groundwater at the boundary between the Upper Aquifer and the Duwamish Waterway. (No allowance was made in the model for dilution in the Waterway.) The predicted maximum constituent concentrations in groundwater at the Aquifer/Waterway boundary were then compared to available surface water quality standards.

These available standards are considered action levels for the purposes of this fate and transport evaluation and for assessing potential threats to surface water from groundwater discharge. The action levels are as follows:

- **Toluene:** 17,500  $\mu\text{g/l}$  (federal Water Quality Standards, 40 CFR Part 131; maximum value; no chronic criterion available)
- **Pentachlorophenol:** 4.91  $\mu\text{g/l}$  (MTCA Method B cleanup level for surface water, WAC 173-340)

- **Copper:** 11.06 to 19.21  $\mu\text{g/l}$  (varies based on water hardness; Federal Water Quality Standards, 40 CFR Part 131)
- **Chromium:** 224  $\mu\text{g/l}$  (for trivalent chromium, based on a groundwater hardness of 110 mg/l at Upper Aquifer monitoring well DM-5; federal Water Quality Standards, 40 CFR Part 131)

There are no applicable surface water quality standards for acetone and 2-methylphenol.

A two-phased approach was used to estimate concentrations in groundwater at the Duwamish Waterway. First, a conservative screening-level analysis was performed for the six constituents listed in Table 4-29 in order to determine whether any constituent could possibly be expected to discharge to the Duwamish Waterway at a concentration exceeding action levels. Constituents that were found to exceed action levels as a result of this screening-level analysis were further evaluated using Bioplume II, a more sophisticated numerical flow and transport model that considers constituent attenuation by biodegradation and adsorption. These evaluation methods and their results are discussed in the following two sections.

### *Screening-Level Estimates of Constituent Concentrations in Groundwater*

**Approach.** A simple analytical model that considers steady one-dimensional flow and two-dimensional dispersion in directions perpendicular to the flow path was applied to the six constituents listed in Table 4-29. The model was used to predict constituent "exit" concentrations at the Upper Aquifer/Duwamish Waterway boundary based on the presence of plumes of constant concentration at the Facility.

A groundwater constituent is typically subject to a number of physical, chemical, and biological processes along its transport path that tend to reduce its concentration; in some cases these processes will remove the constituent entirely. This screening-level analysis for predicting concentrations is conservative in that it ignores many of these factors, such as chemical and biological reactions. In addition, a constant constituent source was assumed, adding another layer of conservatism to the analysis. As such, this screening process is particularly useful in identifying those constituents that would never be expected to discharge to the Duwamish Waterway at concentrations exceeding action levels.

The governing equations, input parameter calculations, and detailed assumptions used in this analysis are presented in Appendix K.

The analytical model considers the following Facility features:

- The assumed width and depth of each constituent plume (based on the RFI groundwater quality data)



- The distance from the downgradient edge of each plume to the Duwamish Waterway (assumed to be the middle of the intertidal zone)
- The average constituent concentration at the source of the plume (note that dissolved concentration data were used for the two metals evaluated)
- The groundwater flow velocity as calculated from hydraulic conductivity, hydraulic gradient, and porosity (all based on Facility-specific data)
- The dispersivity and dispersion coefficient (estimates based on literature values)

The analysis requires that assumptions be made about the hydrogeology of the Facility. The groundwater flow direction is assumed to be east-northeast to west-southwest, discharging to the Duwamish Waterway. The depth to the groundwater table is assumed to be 12 feet, and the thickness of the Upper Aquifer 50 feet. The groundwater velocity is 0.03 ft/day, consistent with the assumed gradient of 0.002 discussed earlier in Section 4.8.1.

Assumptions about the presence of contamination and the ability of the medium to disperse the contamination were also made for the purposes of this analysis. Five of the constituents included in the analysis were assumed to be present in a plume that extends to a depth of 12 feet in the Upper Aquifer (i.e., the stated concentration is assumed to be representative of the upper 25 percent of the aquifer). Toluene was assumed to extend to a depth of 25 feet (the upper one-half of the aquifer). The concentrations assumed for all the constituent plumes are listed in Table 4-31. The transverse dispersivity for the Upper Aquifer was assumed to be 1 foot. For conditions close to the Duwamish Waterway where tidal effects are greater, a less conservative and more realistic transverse dispersivity of 10 feet was assumed.

Figures 4-54 through 4-59 show the plume locations and concentrations assumed for each of the six constituents modeled.

It should be noted that the concentration for the toluene plume was assumed to be 100,000  $\mu\text{g/l}$  in the upper 25 feet of the Upper Aquifer. This is a simplification of actual plume conditions (see Figures 4-47 to 4-50). Actual toluene data indicate that toluene concentrations greater than 100,000  $\mu\text{g/l}$  only occur in the upper 10 feet of the Upper Aquifer and concentrations greater than 10,000  $\mu\text{g/l}$  are restricted to the upper 20 feet of the Upper Aquifer. Upper Aquifer toluene concentrations range from 110 to 1,200  $\mu\text{g/l}$  in the lower 30 feet of the aquifer (Figures 4-49 and 4-50). Given the actual magnitude and distribution of toluene in the Upper Aquifer, the assumption that 100,000  $\mu\text{g/l}$  of toluene is uniformly distributed in the upper 25 feet is considered conservative for this screening-level analysis.

**Results.** Table 4-31 presents the results of the screening-level fate and transport analysis. The table indicates the assumed depth and width of each constituent plume and its assumed

average concentration, the distance from the edge of the plume to the middle of the intertidal zone in the Duwamish Waterway (including a factor of 1.4 to account for net movement throughout a tidal cycle), and the predicted concentration at the Waterway for assumed values of dispersivity of the aquifer system. Table 4-31 also shows action levels (surface water quality standards are available for four of the six constituents) for purposes of comparison. Hardness-dependent surface water quality criteria for chromium and copper were calculated using a groundwater hardness of 110 mg/l (at well DM-5) and 210 mg/l (the average for wells DM-2A and DM-8), based on actual calcium and magnesium groundwater concentrations measured at the Facility.

As can be seen from Table 4-31, the predicted exit concentrations at the Upper Aquifer/Duwamish Waterway boundary are less than the action levels, with the exception of copper (for the 1-foot dispersivity case, in the vicinity of wells DM-2A and DM-8) and toluene. No state or federal surface water standards are available for acetone or 2-methylphenol. The predicted exceedances for copper and toluene are discussed below.

The predicted concentration for copper exiting to the Duwamish Waterway from the vicinity of wells DM-2A and DM-8 is 20.4  $\mu\text{g/l}$  for the 1-foot dispersivity case. This just exceeds the action level (federal water quality criterion of 19.21  $\mu\text{g/l}$ ) for copper (a criterion based on a hardness of 210 mg/l). The assumed source concentration for copper in groundwater at DM-2A and DM-8 was 46  $\mu\text{g/l}$ , the average for the dissolved copper concentrations detected at the two wells during Round 1 of the RFI.

Given the proximity of wells DM-2A and DM-8 to the Waterway, a higher value of transverse dispersivity may be more realistic. Advective and dispersive fluxes are significantly higher close to the shoreline than they are farther inland. When the exit copper concentration was re-evaluated using the same transport analysis but using a higher, less conservative dispersivity of 10 feet, the resulting estimated copper concentration at the Upper Aquifer/Duwamish Waterway boundary is 10.8  $\mu\text{g/l}$ , less than the action level.

Using a dispersivity of 1 foot yields an exit copper concentration that is relatively close to the action level. Using a dispersivity of 10 feet yields an exit copper concentration that is less than the criterion. However, it is expected that the actual copper concentration at wells DM-2A and DM-8 will decrease with time now that the Facility is closed and the copper sources have been or are being removed.

The action level (maximum federal Water Quality Standard) for toluene is 17,500  $\mu\text{g/l}$ ; the concentration predicted in this analysis for groundwater discharging to the Waterway from the Upper Aquifer is 64,068  $\mu\text{g/l}$  for the 1-foot dispersivity case and 43,221  $\mu\text{g/l}$  for the 10-foot dispersivity case. It should be noted that the toluene concentration at the eastern edge of the Duwamish Waterway predicted by this analysis is far greater than what has been observed at the Facility. The RFI sampling indicates that the toluene is not migrating offsite in any direction and, more specifically, is not migrating to the Duwamish Waterway or Slip No. 6. This is evidenced by data from several Upper Aquifer monitoring wells located along the shoreline on the south and east sides of the Facility. The configuration of

the toluene plume (a steep concentration gradient, as shown in Figure 4-48) indicates that toluene is undergoing chemical or biological degradation that is not considered in this screening-level analysis. Therefore, toluene was further analyzed using more sophisticated modeling techniques as discussed in the following section.

### ***Bioplume II Modeling of Toluene Concentrations in Groundwater***

The conservative screening-level analysis discussed above indicates that toluene could potentially exceed action levels in groundwater discharging to the Duwamish Waterway. As a result, Bioplume II, a numerical flow and transport model developed with U.S. EPA's cooperation, was applied to the Facility to further refine estimates of toluene concentrations over time in Upper Aquifer groundwater. The primary objective of the Bioplume II evaluation was to consider the potential attenuation of the toluene plume caused by biodegradation. It is a logical follow-on to the screening-level analysis.

**Approach.** Bioplume II, a two-dimensional steady-state groundwater flow and transient contaminant transport model, was used to provide a more realistic estimate of toluene concentrations at the Facility. This model goes beyond the preliminary screening analysis in that it considers the effects of anaerobic and aerobic biodegradation, longitudinal dispersion, and chemical retardation on toluene concentrations. It is also capable of simulating both instantaneous and constant contaminant sources. The Bioplume II model is discussed in more detail in Appendix K.

It is important to note that this approach does not consider variations in groundwater concentrations with depth in the Upper Aquifer. HydroPunch and monitoring well data have indicated that the majority of toluene contamination is within the upper half of the 50-foot-thick aquifer. The model assumes that the concentrations are also representative of toluene at depth in the aquifer; therefore, this approach is conservative in that it does not consider vertical dispersion that could potentially occur.

Two scenarios were modeled using Bioplume II:

1. An instantaneous source (i.e., the existing constituent plume represents all the toluene that is available to groundwater; no further toluene is introduced to the system over time).
2. A constant source (i.e., the existing constituent plume is used to represent initial conditions, and contaminated soils are assumed to provide a constant source of pure-phase toluene over time). For this model, the constant source was represented in the model using injections wells in four cells representing an area where toluene concentrations in soil are known to be high. The constituent was introduced at a rate that was calculated using mass-balance techniques. This scenario represents a worst-case condition.

Figures 4-60a and 4-61a show the concentration distribution for the initial condition that was assumed for both scenarios. Figures 4-61b through 4-61d indicate the locations where toluene is introduced to groundwater from overlying soil in the constant-source scenario.

Groundwater flow was modeled to simulate an average or net gradient occurring over a tidal cycle. Constant head nodes were used to represent the current understanding of the Facility hydraulics (e.g., a radial flow pattern at low tide toward the Duwamish Waterway and Slip No. 6). Appendix K describes the input parameters for the Bioplume II model, including the grid geometry, constant hydraulic head values, aquifer parameters, chemical sorption coefficients, biodegradation rates, and dissolved oxygen concentrations assumed to be available for aerobic biodegradation.

**Results of Instantaneous Contaminant Source Scenario.** The Bioplume II model was used to simulate transport of the toluene plume as it is currently known to exist in groundwater at the site for elapsed periods of 10, 25, and 50 years. This scenario assumes that no additional toluene is leached from overlying soil to groundwater over time. The results are presented as Figures 4-60a through 4-60d, and show the assumed initial toluene concentration and the concentrations of toluene estimated by the model to occur in groundwater at 10, 25, and 50 years from the present time. All toluene concentrations at the site had decreased to below 1 mg/l after 52 years.

The results indicate that in the case of an instantaneous source, the toluene from the plume would not enter the Duwamish Waterway or Slip No. 6 at concentrations exceeding the action level of 17,500  $\mu\text{g/l}$ . Biodegradation (primarily anaerobic) would have a significant effect in attenuating toluene concentrations within the plume. (See Appendix K for further discussion of the effects of biodegradation.)

**Results of Constant Contaminant Source Scenario.** The Bioplume II model was also used to simulate the transport of toluene when a constant source is introduced to groundwater. Estimates of toluene concentrations were made for elapsed periods of 10, 50, and 100 years. The results of this analysis are presented as Figures 4-61a through 4-61d. The red-colored toluene concentration values in Figures 4-61a through 4-61d indicate cells in the model where toluene was injected at a constant rate over time, in order to simulate releases of toluene from soil to groundwater. The results indicate that in the case where a constant source of toluene is introduced to groundwater, the toluene from the plume would not enter the Duwamish Waterway or Slip No. 6 at concentrations exceeding the action level of 17,500  $\mu\text{g/l}$ . In this case, biodegradation (primarily anaerobic) of toluene appears to balance the continual leaching of the constituent from soil to groundwater. (See Appendix K for further discussion of the effects of biodegradation.) Figure 4-61 shows that concentrations at the Duwamish Waterway and Slip No. 6 do not exceed 3,000  $\mu\text{g/l}$  at 50 years or 100 years, despite the assumed constant source in the area of contaminated soils.

### 4.8.3 Summary of Fate and Transport Analyses

The fate and transport analyses indicated that toluene was the only constituent (of the six analyzed) that warranted use of more sophisticated techniques to address its potential impact on the Duwamish Waterway. Screening-level analyses indicated that surface water action levels for the other constituents (acetone, 2-methylphenol, pentachlorophenol, dissolved copper, and dissolved chromium) were not exceeded at the Upper Aquifer/Duwamish Waterway boundary. As such, these constituents are not considered to be of concern, and do not warrant further action.

Further modeling was performed to determine whether toluene might be naturally attenuated to acceptable concentrations as a result of biological degradation. The results of the Bioplume II modeling indicate that anaerobic biodegradation is a significant degradation mechanism for toluene at the Facility. Simulation of an instantaneous toluene source using Bioplume II indicates that anaerobic biodegradation would significantly reduce concentrations of toluene in groundwater, such that the surface water action level (17,500  $\mu\text{g/l}$ ) is not exceeded at the Upper Aquifer/Duwamish Waterway boundary. Under the extremely conservative assumption that a constant source of pure-phase toluene from overlying soils is indefinitely available for continuous leaching into the plume, the model results indicate that anaerobic biodegradation also reduces concentrations such that toluene in groundwater at the Aquifer/Waterway boundary will not exceed the surface water action level. The Bioplume II modeling results indicate that biodegradation may be a viable remedial alternative for toluene at the Facility.

### 4.9 References

Bouwer, H. "The Bouwer and Rice Slug Test: An Update." *Groundwater*, vol. 27, no. 3, 1989, pp. 304-309.

Bouwer, H., and R.D. Rice. "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells." *Water Resources Research*, vol. 12, 1976, pp. 423-428.

Dames & Moore. *Phase II, Site Screening Investigation, Final Report*. Prepared for Rhône-Poulenc Inc., Seattle, Washington, October 1986.

Dames & Moore. *Report of Phase II Soils Investigation*. Prepared for Monsanto Chemicals Company, 1979.

Landau Associates, Inc. *Site Assessment, Rhône-Poulenc Facility, Tukwila, Washington*. Prepared for Boeing Environmental Affairs, Seattle, Washington, September 1991.

South King County Ground Water Advisory Committee. *South King County Ground Water Management Plan*. Prepared for the Washington State Department of Ecology, April 1991.

Washington State Department of Ecology. *Elliott Bay Waterfront Decontamination Study, Literature Search*. Prepared for the Elliott Bay/Duwamish Restoration Program, June 1993.

Washington State Department of Ecology. Personal communication between Dr. Theresa Michelsen, Department of Ecology, and Marian Allen McDermott, CH2M HILL, October 27, 1994.

Washington State Department of Ecology. *Statistical Guidance for Petroleum-Contaminated Soil Cleanup Level Determinations*. July 1991.

sca1002A45E.wp5



## Section 5

### Conclusions and Recommendations

Data obtained during the two rounds of field sampling and analysis, as presented in this draft RFI Report, have provided information that meets the objectives of the RFI. These objectives were to:

- Characterize the environmental setting at the Facility.
- Assess the nature and extent of contamination originating from releases of hazardous wastes and/or constituents from the Facility.
- Determine whether further actions are warranted and, in particular, whether a Corrective Measures Study (CMS) is warranted, based on a comparison of concentrations of detected constituents to action levels.

As stated in the RFI Workplan, a secondary objective of the RFI was to confirm and augment information on Facility conditions that had been developed by Dames & Moore (1986) and Landau Associates (1991). This secondary objective was also met. In general, the results of the RFI were consistent with the conceptual model of the Facility developed from pre-RFI data.

#### 5.1 Conclusions

The following conclusions are made based on the data presented in this draft RFI Report:

1. The RFI data, in combination with previously developed data, provide information that characterizes the hydrogeology and environmental setting of the Facility. The physical properties of subsurface materials have been identified, and groundwater flow directions and gradients have been assessed in adequate detail to allow necessary fate and transport analyses of possible constituents of concern. The hydrogeologic characterization demonstrated that:
  - The conceptual hydrogeologic model presented in previous Facility investigation reports is valid.
  - The Facility is underlain by two distinct aquifers—the Upper and Lower Aquifers. The two aquifers are separated by a low-permeability silt and clay stratum that acts as an aquitard. The aquitard is laterally continuous beneath the Facility. The permeability of the aquitard is low, on the order of  $10^{-4}$  ft/day (approximately



10<sup>-8</sup> cm/sec.), and inhibits the downward migration of constituents from the Upper Aquifer to the Lower Aquifer.

- Groundwater levels in both the Upper and Lower Aquifers are tidally influenced. The hydraulic gradient between the Upper and Lower Aquifers (across the aquitard) is in the upward direction at all times, regardless of the tide stage, and also inhibits the downward migration of constituents from the Upper Aquifer to the Lower Aquifer.
  - Under normal conditions, the net groundwater flow direction beneath the Facility is believed to be from east to west (toward the Duwamish Waterway and Slip No. 6). However, a groundwater extraction program being conducted at the Kenworth site (immediately north of the Facility) appears to cause a northward net groundwater flow direction in the western portion of the Facility.
2. The results of the soil, groundwater, sediment, and air emissions investigations have provided a comprehensive identification of the nature and extent of contamination at the Facility. The RFI results are, in general, consistent with information developed during previous Facility investigations as well as with documented results for constituents present in environmental media within the region.
  3. Only two constituents were found to exceed action levels for soil: Arsenic and mercury were detected once each at concentrations exceeding their action levels. Arsenic and mercury are not considered to be constituents of concern, however, because their action levels were exceeded only once; arsenic is present in soil at similar levels throughout the region; and during the RFI, a comprehensive investigation of potential mercury contamination demonstrated that the single detection above its action level was an isolated occurrence that could not be confirmed. No other constituents were detected in soil above their respective action levels—including the preliminary constituents of concern identified in the RFI Workplan.
  4. The results of the groundwater investigation indicate that toluene is the primary constituent of concern in groundwater. Specifically, the area of concern is the toluene plume located beneath the Tank Farm. Toluene is present in this area at concentrations above the 1,000 µg/l action level.

Several other organic compounds are present in the toluene plume area at concentrations exceeding action levels. These are of secondary concern because they are less widespread than the toluene and they do not exceed their action levels to the same degree as toluene. Only three metals (arsenic, beryllium, and chromium) were detected in filtered samples at concentrations exceeding action levels. Of these, arsenic and beryllium are not known to

have been used at the Facility, and arsenic is known to be present regionally at high concentrations. Groundwater chemistry data indicate that chromium exists in the trivalent form and not in the more toxic hexavalent form that the action level presumes. Therefore, arsenic, beryllium, and chromium are not considered constituents of concern for the Facility.

5. Light nonaqueous phase liquid (LNAPL) is currently not present in significant volumes beneath the Facility. Pre-RFI chemical characterization of the LNAPL indicates that it is composed primarily of non-toxic food-grade mineral oil.
6. Fate and transport analyses were conducted for several constituents of concern to evaluate the potential for discharge of contaminated groundwater to the Duwamish Waterway at concentrations exceeding applicable surface water criteria. Because toluene is known to be biodegradable—susceptible to both aerobic and anaerobic biodegradation—the Bioplume II fate and transport model was used to assess the potential for offsite migration of toluene under conservative assumptions. The model results indicate that anaerobic biological decomposition of toluene will significantly reduce toluene concentrations. The results also indicate that degradation of the plume, as predicted by the model, will occur such that toluene will not be discharged to the Duwamish Waterway at concentrations exceeding applicable surface water quality criteria.

Data collected from Facility groundwater monitoring wells support these findings. The toluene plume is not encroaching on the shoreline, and toluene is not discharging to the Duwamish Waterway. Further, a comparison of data collected over time (1986 to 1994) by Dames & Moore, Landau Associates, and RPI indicates that the toluene plume is not migrating.

7. The sediment sampling results indicate that constituents were not detected above action levels or concentrations documented to be present in the Duwamish Waterway/Elliott Bay area. Therefore, sediments are not a medium of concern.
8. Volatile organic compounds were detected at very low levels during the air emissions investigation. The detected concentrations are low compared to applicable regulatory thresholds and ambient conditions. Therefore, air is not a medium of concern.

## 5.2 Recommendations for Future Actions

As stated in Section 1 of this draft RFI Report and consistent with current U.S. EPA guidance as presented in the final RCRA Corrective Action Plan (Directive 9902.3-2A,

May 31, 1994), one of the objectives of an RFI is to evaluate the need for a CMS. Typically, the primary consideration in such an evaluation is to identify constituents that are present (1) in environmental media as a result of a past release from a Solid Waste Management Unit (SWMU) and (2) at concentrations that exceed action levels. An exceedance of an action level under these circumstances typically "triggers" the need for a CMS. Conversely, a CMS is generally considered unnecessary if no exceedance occurs.

Based on these criteria and the conclusions cited above, RPI recommends that a CMS be conducted to evaluate the need for, and the scope of, remedial measures addressing the toluene plume present in groundwater in the Upper Aquifer. A CMS addressing constituents in the other environmental media (soil, sediments, and air) is not warranted because constituents present in these media as the result of past releases from SWMUs were not detected at concentrations above their respective action levels.

Pursuant to RPI's Consent Order, the Human Health and Ecological Risk Assessment Report and Proposed Media Cleanup Standards evaluation will be submitted to U.S. EPA 30 days after the final RFI Report. The information developed in these analyses will be used primarily to evaluate the need for, and the scope of, future remedial actions. The Risk Assessment and Media Cleanup Standards evaluation will focus on the toluene plume. Anthropogenic chemical constituents that do not have action levels but were detected in soil and groundwater will also be addressed.

sea1002A466.wp5